Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

School of Physics

Undergraduate Handbook 2018–2019

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Faculty of Engineering, Mathematics and Science

Undergraduate Handbook 2018/19

TR071 *Science* – B.A. Moderatorships in

Physics,
Physics and Astrophysics

TR076 – B.A. Moderatorship in

Nanoscience, Physics and Chemistry of Advanced Materials

TR035 – B.A. Moderatorship in

Theoretical Physics

Senior Fresh Physics for students in

TR071 Science, TR074 Chemistry with Molecular Modelling,

TR077 Earth Sciences, and TR035 Theoretical Physics

Junior Fresh Physics for students in

TR035 Theoretical Physics

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Introduction

Physics lies at the heart of most of science and technology. For example, modern biology seeks to analyse many of the processes of life in terms of physical laws. Recently physics has even been applied to economics. The search for a fundamental understanding and the drive towards technological development in areas such as computer hardware continue to pose fresh challenges to physicists. They are tackled with a combination of experiment, theory and computation. Our degree courses combine all three of these elements and prepare the student for a wide range of careers. Our graduates are in demand for positions in research both here and overseas, and for a wide range of jobs in industry and commerce.

A note on this handbook

This handbook applies to Sophister students in TR071 reading Physics or Physics and Astrophysics, Sophister students in TR076 Nanoscience, Physics and Chemistry of Advanced Materials (N-PCAM), all students in TR035 Theoretical Physics (TP), and Senior Fresh students taking Physics modules as part of TR071 Science, TR074 Chemistry with Molecular Modelling (CMM) and TR077 Earth Sciences. It provides a guide to what is expected of you from the School of Physics in these programmes and the academic and personal support available to you. Junior Fresh students taking Physics in TR060 Biological Sciences, TR061 Chemical Sciences, TR062 Geography and Geosciences, or TR063 Physical Sciences should consult the JF Handbook for their course, which is available at http://www.tcd.ie/Science.

Please note that this handbook only provides information regarding courses, modules, exams etc. in the School of Physics. Students following courses provided jointly with other Schools should also consult relevant information sources in those Schools and in the TR071 Science Course Office.

The information provided in this handbook is accurate at time of preparation. Any necessary revisions or changes will be notified to students via email and School notice boards. Please note that, in the event of any conflict or inconsistency between the General Regulations published in the University Calendar and information contained in this handbook, the provisions of the General Regulations will prevail unless a change has been made during the year.

General School Information

History

The School of Physics has a distinguished history of teaching and research stretching back over 300 years to Richard Helsham, the first Erasmus Smith's Professor of Natural and Experimental Philosophy (1724), who was the first to lay out Newton's methods in a form suitable for the undergraduate in his book *Lectures in Natural Philosophy*, which was in use for a hundred years in the College and elsewhere in Europe. Later holders of the chair include G. F. Fitzgerald, famous in relativity theory, and E. T. S. Walton, the first Irish recipient of a Nobel Prize in a science subject.

Facilities

An elegant, dedicated Physical Laboratory building was completed in 1906 and, with the Sami Nasr Institute for Advanced Materials (SNIAM), which was completed in 2000, houses the central part of the School today. The School, which is housed in these buildings and CRANN, provides excellent modern facilities for teaching and research for a very lively community of over 200 physicists, technical and support staff, including 27 academic staff and approximately 60 postdoctoral fellows and 85 graduate students.

Research

In research, the School has a worldwide reputation and several staff members are recognised as leaders in their fields. Much of this research is funded by Science Foundation Ireland. Inventions and technical developments arising from our research have led to the foundation of several spin-off companies in recent years. Physics is the School with the largest participation in the Centre for Research in Nanoscience and Nanodevices (CRANN), which is located in the Naughton Institute and has excellent research facilities including a state-of-the-art suite of electron and ion microscopes in the AML (Advanced Microscopy Laboratory). Many staff members and research students in the School of Physics carry out research in CRANN. The School is also a major participant in Research IT which is the Trinity centre for high performance computing, which is housed in the adjacent Lloyd building, named for Bartholomew Lloyd and his son, Humphrey, who both worked in Trinity in the 19th century and made important contributions in mathematics, mathematical physics, optics and the study of terrestrial magnetism. The School also has programmes of cooperation with both the School of Cosmic Physics, Dublin Institute for Advanced Studies (DIAS) and with Armagh Observatory.

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Programme Overview

The School of Physics offers four Moderatorship (honors degree) courses in which Physics is a main component. In addition, students in the Junior and Senior Fresh (first and second) years reading Chemistry with Molecular Modelling and Science students who do not intend to take one of the Physics Moderatorships may choose to take the Physics modules offered for their course of study. Students reading Earth Sciences take one prescribed Physics module in each of the first two years.

TR071 – Science – Physics

Physics is the core moderatorship in the School of Physics. Building on the courses taken in the first two years, students follow in-depth courses (theory, experiment and computational) across the spectrum of modern physics. There is a particular emphasis on condensed-matter physics, reflecting the School's research strength in this area. Students who wish to proceed to a degree in Physics must take the prescribed modules in Physics (20 credits) and Mathematics (20 credits) in both first and second years. In the Junior and Senior Sophister (third and fourth) years students take a variety of specialist Physics modules. In the first 9 weeks of the Senior Sophister year students work full time on a research project in one of the research groups in the School, CRANN or at another institution.

Course Outcomes for Physics

On successful completion of this course, students should be able to:

a) Demonstrate in written and oral form a comprehensive level of knowledge of physics and of the mathematics that underpins this knowledge, together with an awareness of its place within the broader science curriculum
b) Apply the core concepts of Classical and Modern Physics across a wide spectrum of topics and applications, such as information technology and materials science
c) Perform calculations to solve practical problems, including the use of numerical methods and computing
d) Operate sophisticated spectrometers and similar test and evaluation apparatus, across a wide spectrum of investigation
e) Independently design and carry out an experiment and evaluate critically the data obtained, including appropriate error analysis
f) Communicate the results of an experiment or project via dissertation, poster and oral presentation
g) Employ literature search methods to obtain information relevant to research and development

h) Act effectively as an individual or as a member of a team in professional, educational and industrial settings
i) Update personal knowledge with a high degree of autonomy, whether in the workplace or in the context of further study

TR071 – Science – Physics and Astrophysics

Students follow the TR071 Science course in their Junior and Senior Fresh years and must take prescribed modules in Physics (20 credits) and Mathematics (20 credits) in both years. The Physics course in these first two years includes introductory Astrophysics lectures. In the Junior and Senior Sophister (third and fourth) years students take a variety of specialist astrophysics and computational modules as well as core Physics modules. In the first 9 weeks of the Senior Sophister year students work full time on a research project either in Physics or Astrophysics. Projects in Astrophysics take place in one of the Astrophysics research groups in the School, the School of Cosmic Physics, Dublin Institute for Advanced Studies (DIAS), Armagh Observatory or at another institution/observatory.

Course Outcomes for Physics and Astrophysics
On successful completion of this course, students should be able to:

a) Demonstrate in written and oral form a comprehensive level of knowledge of physics and astrophysics and the mathematics that underpins this knowledge, together with an awareness of its place within the broader science curriculum
b) Apply the core concepts of Classical and Modern Physics across a wide spectrum of topics and applications, such as information technology and materials science
c) Perform calculations to solve practical problems, including the use of numerical methods and computing
d) Perform advanced numerical calculations using appropriate program design and execution
e) Independently design and carry out an experiment and evaluate critically the data obtained, including appropriate error analysis
f) Communicate the results of an experiment or project via dissertation, poster and oral presentation
g) Employ literature search methods to obtain information relevant to research and development
h) Act effectively as an individual or as a member of a team in professional, educational and industrial settings
i) Update personal knowledge with a high degree of autonomy, whether in the workplace or in the context of further study

TR035 – Theoretical Physics

This course is taught jointly by the Schools of Mathematics and Physics. In the first two years students (Freshers) take prescribed Physics modules (20 credits) and Mathematics modules (40 credits). In the Junior and Senior Sophister (third and fourth) years, the Physics and Mathematics courses contribute more or less equally to the Theoretical Physics course (depending upon the options chosen in the Senior Sophister year). In the Senior Sophister (fourth) year students will do an extended project in either the School of Physics or the School of Mathematics. Students should consult relevant information sources in the School of Mathematics for details of modules, requirements etc. in Mathematics.

Course Outcomes for Theoretical Physics

On successful completion of this course, students should be able to:

a) Tackle a wide range of topics using powerful analytical tools, including formal methods in classical and quantum physics
b) Clearly communicate information and conclusions in written and verbal formats on core ideas in Theoretical Physics
c) Evaluate complex problems and formulate solutions, identifying the role of theory, hypothesis and experiment in the scientific method
d) Apply computers to the solution of problems in theoretical physics
e) Plan, carry out and report a theoretical-physics-based investigation
f) Apply classical and quantum theoretical techniques in research
g) Work independently in a research environment and as part of a research team
h) Undertake professional work in physics at a high level

TR076 – Nanoscience, Physics and Chemistry of Advanced Materials

Nanoscience, Physics and Chemistry of Advanced Materials is a four-year course taught jointly by the Schools of Physics and Chemistry. In the first two years, students take prescribed modules in Physics (20 credits), Chemistry (20 credits) and Mathematics (20 credits). Specialized lectures and tutorial classes, introducing students to the study of materials are included. In the Junior and Senior Sophister (third and fourth) years, students study core topics in Physics and Chemistry along with some specialized modules in Advanced Materials, which includes Nanoscience. Junior Sophister students take an Advanced Materials laboratory class including an introduction to experimental techniques for Nanoscience that is carried out in the research laboratories in CRANN. In the first 9 weeks of the Senior Sophister year students work full time on a research project. In many cases, students travel abroad to conduct research in an academic or industrial research laboratory. Students should consult relevant information sources in the School of Chemistry for details of modules, requirements etc. in Chemistry.

Course Outcomes for Nanoscience, Physics and Chemistry of Advanced Materials
On successful completion of this course, students should be able to:

a) Articulate in written and oral form a foundation level of knowledge and understanding of Physics, Chemistry and Mathematics
b) Apply key concepts in Physics and Chemistry and key concepts in the Physics and Chemistry of Materials for the design of materials with novel properties
c) Design, perform, and analyse the results obtained from experiments in materials physics and chemistry using modern physical and chemical experimental methodologies and instrumentation, with particular reference to materials
d) Demonstrate skills in problem-solving, critical thinking and analytical reasoning, and be able to effectively communicate the results of their work to chemists, physicists, material scientists and others, both verbally and in writing
e) Use modern library searching and retrieval methods to obtain information pertinent to the identification and solution of problems in the physics and chemistry of materials, and the exploration of new research areas
f) Work effectively and safely in a laboratory environment operating within the proper procedures and regulations for safe handling and use of chemicals and instruments
g) Design and perform appropriate experiments to address materials physics and chemistry problems, and analyse the results
h) Update their knowledge and undertake further study with a high degree of autonomy.

Programme Regulations

Assessment and examination procedures

All students take modules totalling 60 credits in each year. Each module must be passed for a student to be deemed to have passed the year. The pass mark is 40%. Overall marks and grades are calculated according to a weighted average based on the number of credits for each module.

In cases where a student does not achieve the pass mark in all modules, they will be deemed to pass the year 'by compensation' if they (i) achieve an overall credit-weighted average of at least the pass mark, and (ii) achieve the pass mark in modules carrying a minimum of 50 credits, and a mark of at least 35% in any remaining module(s).

Students who do not pass the year at the first sitting must present for reassessment in all failed modules at the supplemental session.

For JF and SF Physics for all courses: Each physics module (5 or 10 credits) is examined separately at the end of the semester in which it is taught. The module mark is calculated by combining the mark from the exam with the appropriate continuous assessment marks (laboratory, project, tutorials).

For Physics, and Physics and Astrophysics Sophisters, assessment is based on a total of 60 credits in Physics which includes a 20-credit practical module in JS, and a 20-credit project in SS. JS students may choose to take a 5-credit Broad Curriculum module. In this case they take a practical module with reduced credits (15 credits).

For Theoretical Physics, in the Junior Sophister year assessment is based on 30 credits in Physics and 30 credits in Mathematics. In the SS year students must take taught modules amounting to at least 20 credits in each of Mathematics and Physics. They must also take a 10 credit research project in either Mathematics or Physics. The remaining 10 credits may be chosen from either or both subjects, or 5 credits from either subject plus a 5 credit Broad Curriculum module.

For Nanoscience, Physics and Chemistry of Advanced Materials, assessment is based on 20 credits in Physics, combined with the balance of credits in Chemistry and Mathematics in the JF and SF years. In the Sophister years students take Physics and Chemistry modules and practical laboratory classes (JS) and a research project (SS).

Modules in Physics are assessed by end-of-semester examination and by continuous assessment where indicated in the *Index of Modules* (see p 46ff). Modules (e.g. laboratory, project, communication skills, seminars) may have 100% continuous assessment.

Scholarships, Prizes and Awards

School of Physics Scholarships – these are awarded to four incoming students in Junior Fresh based on their Leaving Certificate (or equivalent) grades. Students should have a H1 or H2 in Physics, be taking 20 credits in Physics in the JF year and intend to take one of the physics degrees. The scholarships are valued at €750 and are paid at the beginning of Hilary Term. Two of these scholarships will be reserved for incoming JF female students.

Fitzgerald Medal – awarded to a candidate who obtains a first-class moderatorship in any of the Physics degrees and who has shown outstanding merit.

Walton Prize – awarded to the student who gives the most meritorious performance in the Junior Fresh physics course (20 credits).

Minchin Prize – awarded annually to two students who have performed with particular merit in the work of the previous Junior Sophister year in mathematics and/or physics.

Henderson-Lloyd Prize – awarded to the student who has obtained the highest marks in the moderatorship examination in Nanoscience, Physics and Chemistry of Advanced Materials.

European Credit Transfer System (ECTS)

The ECTS is an **academic credit transfer and accumulation system** representing the student workload required to achieve the specified objectives of a study programme. The ECTS weighting for a module is a **measure of the student input or workload** required for that module, based on factors such as the number of contact hours, the number and length of written or verbally presented assessment exercises, class preparation and private study time, laboratory classes, examinations, clinical attendance, professional training placements, and so on, as appropriate. There is no intrinsic relationship between the credit value of a module and its level of difficulty.

In College, **1 ECTS credit is defined as 20-25 hours** of student input, so a 10-credit module will be designed to require 200-250 hours of student input, including class contact time and assessments. The College norm for **full-time** study over one academic year at **undergraduate level** is 60 credits. **ECTS credits are awarded to a student only upon successful completion of the course year**. Progression from one year to the next is determined by the course regulations. Students who fail a year of their course will not obtain credit for that year even if they have passed certain component modules. Exceptions to this rule are one-year and part-year visiting students, who are awarded credit for individual modules that are completed successfully.

Plagiarism

The School of Physics strictly implements Trinity College's policy on plagiarism which is reproduced below.

Plagiarism (excerpt from the College Calendar)

96 General
It is clearly understood that all members of the academic community use and build on the work and ideas of others. It is commonly accepted also, however, that we build on the work and ideas of others in an open and explicit manner, and with due acknowledgement.

Plagiarism is the act of presenting the work or ideas of others as one's own, without due acknowledgement.

Plagiarism can arise from deliberate actions and also through careless thinking and/or methodology. The offence lies not in the attitude or intent ion of the perpetrator, but in the action and in its consequences.

It is the responsibility of the author of any work to ensure that he/she does not commit plagiarism.

Plagiarism is considered to be academically fraudulent, and an offence against academic integrity that is subject to the disciplinary procedures of the University.

97 Examples of Plagiarism

Plagiarism can arise from actions such as:
(a) copying another student's work;
(b) enlisting another person or persons to complete an assignment on the student's behalf;
(c) procuring, whether with payment or otherwise, the work or ideas of another;
(d) quoting directly, without acknowledgement, from books, articles or other sources, either in printed, recorded or electronic format, including websites and social media;
(e) paraphrasing, without acknowledgement, the writings of other authors.

Examples (d) and (e) in particular can arise through careless thinking and/or methodology where students:
(i) fail to distinguish between their own ideas and those of others;
(ii) fail to take proper notes during preliminary research and therefore lose track of the sources from which the notes were drawn;
(iii) fail to distinguish between information which needs no acknowledgement because it is firmly in the public domain, and information which might be widely known, but which nevertheless requires some sort of acknowledgement;
(iv) come across a distinctive methodology or idea and fail to record its source.

All the above serve only as examples and are not exhaustive.

98 Plagiarism in the context of group work

Students should normally submit work done in co-operation with other students only when it is done with the full knowledge and permission of the lecturer concerned. Without this, submitting work which is the product of collaboration with other students may be considered to be plagiarism.

When work is submitted as the result of a group project, it is the responsibility of all students in the group to ensure, so far as is possible, that no work submit ted by the group is plagiarised. In order to avoid plagiarism in the context of collaboration and group work, it is particularly important to ensure that each student appropriately attributes work that is not their own.

99 Self plagiarism

No work can normally be submitted for more than one assessment for credit. Resubmitting the same work for more than one assessment for credit is normally considered self-plagiarism.

100 Avoiding plagiarism

Students should ensure the integrity of their work by seeking advice from their lecturers, tutor or supervisor on avoiding plagiarism. All schools and departments must include, in their handbooks or other literature given to students, guidelines on the appropriate methodology for the kind of work that students will be expected to undertake. In addition, a general set of guidelines for students on avoiding plagiarism is available on http://tcd-ie.libguides.com/plagiarism

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If plagiarism as referred to in §96 above is suspected, in the first instance, the Director of Teaching and Learning (Undergraduate), or their designate, will write to the student, and the student's tutor advising them of the concerns raised . The student and tutor (as an alternative to the tutor, students may nominate a representative from the Students' Union) will be invited to attend an informal meeting with the Director of Teaching and Learning (Undergraduate), or their designate, and the lecturer concerned, in order to put their suspicions to the student and give the student the opportunity to respond. The student will be requested to respond in writing stating his/her agreement to attend such a meeting and confirming on which of the suggested dates and times it will be possible for the m to attend. If the student does not in this manner agree to attend such a meeting, the Director of Teaching and Learning (Undergraduate), or designate, may refer the case directly to the Junior Dean, who will interview the student and may implement the procedures as referred to under CONDUCT AND COLLEGE REGULATIONS §2.

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If the Director of Teaching and Learning (Undergraduate), or designate, forms the view that plagiarism has taken place, he/she must decide if the offence can be dealt with under the summary procedure set out below. In order for this summary procedure to be followed, all parties attending the informal meeting as noted in §101 above must state their agreement in writing to the Director of Teaching and Learning (Undergraduate), or designate. If one of the parties to the informal meeting withholds his/her written agreement to the application of the summary procedure, or if the facts of the case are in dispute, or if the Director of Teaching and Learning (Undergraduate), or designate, feels that the penalties provided for under the summary procedure below are inappropriate given the circumstances of the case, he/she will refer the case directly to the Junior Dean, who will interview the student and may implement the procedures as referred to under CONDUCT AND COLLEGE REGULATIONS §2.

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If the offence can be dealt with under the summary procedure, the Director of Teaching and Learning (Undergraduate), or designate, will recommend one of the following penalties:
(a) Level 1: Student receives an informal verbal warning. The piece of work in question is inadmissible. The student is required to rephrase and correctly reference all plagiarised elements. Other content should not be altered. The resubmitted work will be assessed and marked without penalty;
(b) Level 2: Student receives a formal written warning. The piece of work in question is inadmissible. The student is required to rephrase and correctly reference all plagiarised elements. Other content should not be altered. The resubmitted work will receive a reduced or capped mark depending on the seriousness/extent of plagiarism;
(c) Level 3: Student receives a formal written warning. The piece of work in question is inadmissible. There is no opportunity for resubmission with corrections. Instead, the student is required to submit a new piece of work as a reassessment during the next available session. Provided the work is of a passing standard, both the assessment mark and the overall module mark will be capped at the pass mark. Discretion lies with the Senior Lecturer in cases where there is no standard opportunity for a reassessment under applicable course regulations.

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Provided that the appropriate procedure has been followed and all parties in §101 above are in agreement with the proposed penalty, the Director of Teaching and Learning (Undergraduate) should in the case of a Level 1 offence, inform the course director and where appropriate the course office. In the case of a Level 2 or Level 3 offence, the Senior Lecturer must be notified and requested to approve the recommended penalty. The Senior Lecturer may approve, reject, or vary the recommended penalty, or seek further information before making a decision. If the Senior Lecturer considers that the penalties provided for under the summary procedure are inappropriate given the circumstances of the case, he/she may also refer the matter directly to the Junior Dean who will interview the student and may implement the procedures as referred to under CONDUCT AND COLLEGE REGULATIONS §2. Notwithstanding his/her decision, the Senior Lecturer will inform the Junior Dean of all notified cases of Level 2 and Level 3 offences accordingly. The Junior Dean may nevertheless implement the procedures as referred to under CONDUCT AND COLLEGE REGULATIONS §2.

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If the case cannot normally be dealt with under the summary procedures, it is deemed to be a Level 4 offence and will be referred directly to the Junior Dean. Nothing provided for under the summary procedure diminishes or prejudices the disciplinary powers of the Junior Dean under the 2010 Consolidated Statutes
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Non-satisfactory attendance and course work

The School of Physics strictly implements Trinity College's policy on non-satisfactory attendance and course work which is reproduced below. In order to ensure that students are properly trained for laboratory work the School of Physics has adopted the following specific policy:

School of Physics Policy on Attendance at Laboratory Practical Classes and Small Group Tutorials

Students who have less than two thirds (2/3rd) of attendance and/or have submitted less than two thirds (2/3rd) of the required reports/exercises/homework etc. in any semester for any reason will be deemed to have unsatisfactory performance. In this case the student will not be eligible to sit the examinations. Exemptions will be considered under exceptional circumstances on a case by case basis.

Trinity College Policy on non-satisfactory attendance and course work (excerpt from the College Calendar)

Course work

24. Students may be required to perform course work as part of the requirements of their course of study. The assessment of course work may be based on the writing of essays, the sitting of tests and assessments, attendance at practical classes and field trips, the keeping and handing in of practical books, the carrying out of laboratory or field projects, and the satisfactory completion of professional placements. The school, department or course office, whichever is appropriate, publishes its requirements for satisfactory performance of course work on school notice-boards and/or in handbooks and elsewhere, as appropriate.

Non-satisfactory attendance and course work

25. All students must fulfil the course requirements of the school or department, as appropriate, with regard to attendance and course work. Where specific requirements are not stated, students may be deemed non-satisfactory if they miss more than a third of their course of study or fail to submit a third of the required course work in any term

26. At the end of the teaching term, students who have not satisfied the school or department requirements, as set out in §§19, 24and 25 above, may be reported as non-satisfactory for that term. Students reported as non-satisfactory for the Michaelmas and Hilary terms of a given year may be refused permission to take their semester two assessment/examinations and may be required by the Senior Lecturer to repeat their year. Further details of procedures for reporting a student as non-satisfactory are given on the College website at https://www.tcd.ie/undergraduate-studies/academic-progress/attendance-course-work.php.

Note Attendance is mandatory for all classes (lectures, tutorials, laboratory session etc.) for all JF (first year) students.

Junior and Senior Fresh Physics

Science and CMM Students (Senior Fresh only)

Physics is offered to Senior Fresh students in TR071 (Science) and TR074 (Chemistry with Molecular Modelling; CMM) as two co-requisite modules. This means that students who choose to take Physics must take both PYU22P10 and PYU22P20 (10 credits each) in Senior Fresh. Students taking these modules must also take the prescribed Mathematics for Scientists modules (total of 20 credits).

The Junior Fresh Physics modules PY1P10 and PY1P20 and the Junior Fresh Mathematics for Scientists modules (20 credits) are prerequisites for taking the SF Physics modules PYU22P10 and PYU22P20.

Physics (20 credits) and Mathematics (20 credits) in both JF and SF are prerequisites for TR071 Science Moderatorships in Physics, and in Physics and Astrophysics.

Earth Science Students (Senior Fresh only)

Senior Fresh students in TR077 (Earth Sciences) take PYU22P30, Physics for Earth Sciences (5 credits).

N-PCAM Students (Senior Fresh only)

Senior Fresh students in TR076 (Nanoscience, Physics and Chemistry of Advanced Materials; N-PCAM) take two co-requisite physics modules, PYU22P10 and PYU22N20. They must also take the prescribed Mathematics for Scientists (total 20 credits) and Chemistry (total 20 credits).

TP Students (Junior and Senior Fresh)

TR035 Theoretical Physics (TP) students take two co-requisite physics modules in each of their first two (Fresher) years (total of 20 credits per year). This means that students take both PY1T10 and PY1T20 (10 credits each) in Junior Fresh and PY2T10 and PY2T20 (10 credits each) in Senior Fresh. TP students must also take the prescribed Mathematics modules (total 40 credits) in each year.

Junior Fresh Physics

TP students

PY1T10 Physics for Theoretical Physics – 10 credits

Michaelmas Term – 46 lectures, practical laboratory, online & small group tutorials

PY1T20 Physics for Theoretical Physics – 10 credits

Hilary Term – 50 lectures, practical laboratory, online & small group tutorials

Further details, including learning outcomes, are given for all modules in the *Index of Modules* p 46ff.

JF Practical Laboratory Classes – Michaelmas Term, Hilary Term

Students attend a 3-hour experimental/computational laboratory once a week.

Homework Problems – Michaelmas Term, Hilary Term

Students are required to complete homework set for each topic taught in each module. Problems are available and solutions are entered online. Lecturers provide a solution class after the homework submission deadline.

JF Small Group Tutorials – Michaelmas Term, Hilary Term

Every student is assigned to a particular member of staff, as one of a small group of students. Tutorials are held every two weeks, and are intended to introduce the students to College and the School, and to provide a forum for discussion of topics in physics. Students are encouraged to suggest topics themselves, and have an opportunity to bring any problems they are having to the attention of the member of staff who leads their group.

Exams

Information about the examinations will be made available on the Examinations Office's website. Each module, PYU11P10/PY1T10 and PYU11P20/PY1T20, is examined in a separate 2 hour examination paper during the relevant end of semester exam session. The overall mark in each module is calculated as the weighted average of the exam mark (60%), the laboratory practical mark (30%) and online tutorial mark (10%). If a student does not achieve a pass grade in a module, the student must either compensate (p. 9), according to the rules of the course they are taking, or sit a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Senior Fresh Physics

Science and **CMM** students

PYU22P10 Classical Physics – 10 credits

Michaelmas Term – 53 lectures, practical laboratory, project, small group tutorials

Science and **CMM** students

PYU22P20 Modern Physics – 10 credits

Hilary Term – 52 lectures, practical laboratory, small group tutorials

N-PCAM students

PYU22P10 Classical Physics– 10 credits

Michaelmas Term – 53 lectures, practical laboratory, project, small group tutorials

PYU22N20 Modern Physics and Materials – 10 credits

Hilary Term – 52 lectures, practical laboratory, small group tutorials

TP students

PY2T10 Classical Physics for Theoretical Physics – 10 credits

Michaelmas Term – 53 lectures, practical laboratory, project, small group tutorials

PY2T20 Modern Physics for Theoretical Physics – 10 credits

Hilary Term – 52 lectures, practical laboratory, small group tutorials

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Practical Laboratory Classes – Michaelmas Term, Hilary Term

All SF students are required to attend one 3-hour laboratory session each week. A series of experiments and computational exercises are provided to illustrate some key results presented in the lecture courses. The experiments are longer than in the JF year and are designed to continue the development of personal initiative as well as experimental and computational skills. Students prepare written reports on these experiments, which are assessed during the year.

Group Study Projects – Michaelmas Term

All students are required to investigate a given topic in Physics and present their findings in the form of a poster. Students work in groups of about four. Projects are carried out in Michaelmas Term.

Small Group Tutorials – Michaelmas Term, Hilary Term

Students are required to attend tutorials, which are intended to deepen their understanding of concepts taught in lectures.

Homework Problems – Michaelmas Term, Hilary Term

Students are required to complete one homework set for each of four topics taught in each module. Problems are available and solutions are entered online. Lecturers provide a solution class after the homework submission deadline.

Exams

Information about examinations will be made available on the Examination Office's website. Each module, PYU22P10/PY2T10 and PYU22P20/PYU22N20/PY2T20, is examined in a separate 2-hour examination paper during the relevant end of semester exam session. The overall mark is calculated as follows: PYU22P10/PY2T10 as the weighted average of the exam mark (60%), the laboratory practical mark (25%), the tutorial mark (10%) and the project mark (5%). PYU22P20/PY22N20/PY2T20 as the weighted average of the exam mark (60%), the laboratory practical mark (30%) and the tutorial mark (10%). If a student does not achieve a pass grade in a module, the student must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Senior Fresh Physics for Earth Sciences

Earth Sciences students

PYU22P30 Physics for Earth Sciences – 5 credits

Michaelmas Term – 24 lectures, practical laboratory, tutorials

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

SF Physics for Earth Sciences Practical Laboratory Classes

Students attend six 3-hour experimental laboratory classes (on alternate weeks).

Tutorials

Students are required to attend tutorials and to complete associated homework.

Exam

Information about examinations will be made available on the Examination Office's website. The Physics for Earth Sciences module, PYU22P30, is examined in an end-of-semester 2-hour examination paper . The overall mark for the module is calculated as the weighted average of the exam mark (60%), the laboratory practical mark (30%) and the tutorial mark (10%). If a student does not achieve a pass grade in the module the student must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exam.

Junior Sophister Physics

The JS year consists of lectures, tutorials and practicals delivered in modules, as listed below. Students receive training in communication skills within the practical module. Students may choose a Broad Curriculum (BC) module. In that case they attend fewer experimental laboratory practical classes.

The following modules are mandatory.

PYU33P01 Quantum Mechanics I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P03 Condensed Matter I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P04 Condensed Matter II – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P05 Atomic & Nuclear Physics – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P06 Dynamical Systems – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P07 Experimental Techniques – 5 credits
Hilary Term – 30 lectures/tutorials

Optional Modules: Students must choose *one* of the following modules:

PYU33A03 Stellar and Galactic Structure – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Michaelmas Term – 30 lectures/tutorials

Students choose between one of the following options:

PYU33PP1 Practical in Physics – 20 credits

Michaelmas Term, Hilary Term – experimental laboratory classes, seminars and communications workshops

OR

PYU33PP2 Practical in Physics with BC– 15 credits

Michaelmas Term, Hilary Term – experimental laboratory classes, seminars and communications workshops and

One Broad Curriculum Module – 5 credits

Michaelmas Term, Hilary Term – See https://www.tcd.ie/Broad_Curriculum/

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period, with the exception of PYU33C01 which is assessed entirely by continuous assessment. If the module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Continuous assessment of the practical module (PYU33PP1) contributes 20 credits. The practical module contributes 15 credits (PYU33PP2) when taken with a 5-credit Broad Curriculum module. JS marks contribute to 35% of the Moderatorship mark.

Junior Sophister Theoretical Physics

The JS year consists of lectures, tutorials and practicals delivered in modules. Students receive training in communication skills within the practical module, as listed below. In their Junior Sophister year students taking the Theoretical Physics Moderatorship course take modules in Mathematics (total 30 credits), together with the following Physics modules (total 30 credits):

Mandatory modules:

PYU33P03 Condensed Matter I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P04 Condensed Matter II – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P05 Atomic & Nuclear Physics – 5 credits
Hilary Term – 30 lectures/tutorials

PY3TP1 Practical in Theoretical Physics – 10 credits
Michaelmas Term, Hilary Term – experimental and computational laboratory classes, seminars and communications workshops

Optional Modules: Students must choose *one* of the following modules:

PYU33A03 Stellar and Galactic Structure – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Michaelmas Term – 30 lectures/tutorials

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period, with the exception of PYU33C01 which is assessed entirely by continuous assessment. If the module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Continuous assessment of the practical module (PY3TP1) contributes 10 credits. The balance of credits is taken from Mathematics modules. JS marks contribute to 35% of the Moderatorship mark in Physics.

Junior Sophister Physics and Astrophysics

The JS year consists of lectures, tutorials and practicals delivered in modules, as listed below. Students receive training in communication skills within the practical module. Students may choose a Broad Curriculum (BC) module. In that case they attend fewer experimental laboratory practical classes.

The following modules are mandatory.

PYU33P01 Quantum Mechanics I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P03 Condensed Matter I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P05 Atomic & Nuclear Physics – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33A03 Stellar and Galactic Structure – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33A06 Statistical Thermodynamics & Astrophysical Spectroscopy – 5 credits
Michaelmas– 30 lectures/tutorials

PYU33A07 Experimental Techniques for Astrophysics – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Michaelmas Term – 30 lectures/tutorials

Students choose between one of the following options:

PYU33AP1 Practical in Physics and Astrophysics – 20 credits
Michaelmas Term, Hilary Term – experimental and computational laboratory classes, seminars and communications workshops

OR

PYU33AP2 Practical in Physics and Astrophysics with BC– 15 credits
Michaelmas Term, Hilary Term – experimental and computational laboratory classes, seminars and communications workshops and
One Broad Curriculum Module – 5 credits
Michaelmas Term, Hilary Term – See https://www.tcd.ie/Broad_Curriculum/

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period, with the exception of PYU33C01 which is assessed entirely by continuous assessment. If the module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Continuous assessment of the practical module (PYU33AP1) contributes 20 credits. The practical module contributes 15 credits (PYU33AP2) when taken with a 5-credit Broad Curriculum module. JS marks contribute to 35% of the Moderatorship mark.

Junior Sophister Nanoscience, Physics and Chemistry of Advanced Materials

Physics for Junior Sophister N-PCAM students consists of lectures and tutorials delivered in modules, as listed below. The balance is made up of prescribed modules in Chemistry (20 credits) and a practical advanced materials module (20 credits), which includes laboratory classes and an introduction to experimental techniques for nanoscience carried out in the research laboratories in CRANN. Students also receive training in communication skills within the practical module.

All modules are mandatory.

PYU33P01 Quantum Mechanics I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33P03 Condensed Matter I – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33P04 Condensed Matter II – 5 credits
Hilary Term – 30 lectures/tutorials

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period. If the module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Continuous assessment of the practical module in Advanced Materials contributes 20 credits. The balance of credits comes from Chemistry modules. JS marks contribute to 35% of the Moderatorship mark.

Senior Sophister Physics

The SS year consists of lectures, tutorials and practicals delivered in modules, as listed below. A major component of the year is an independent research project (PYU44PP2), which is carried out during the first 9 weeks of Michaelmas term. There are no lectures during this period.

All modules are mandatory.

PYU44P01 **Quantum Mechanics and High Energy Physics** – 10 credits
Michaelmas/Hilary Term – 48 lectures/tutorials

PYU4PP03 Condensed Matter and Nanoscience – 10 credits
Michaelmas/Hilary Term – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44P07 Advanced Topics – 5 credits
Hilary Term – 24 lectures/tutorials – Students select 2 topics from the five offered.

PYU44PP2 Physics Research Project – 20 credits
Michaelmas Term, Hilary Term – Research Project

PYU44PP5 Problem Solving in Physics – 5 credits
Michaelmas Term – Problem Solving Tutorials and Seminars

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

In order to pass the year and be awarded a Moderatorship degree every student must pass each module and gain an overall mark of at least 40%. The overall end-of-year mark and grade is calculated based on the credit-weighted average of the module marks. If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period. The 10-credit lecture modules PYU44P01 and PYU44P03 are examined in the examination period following semester 2. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

The problem-solving module PYU44PP5 is assessed by a 3-hour examination in the semester 1 examination period. The project PYU44PP2 is assessed during semester 2.

The final degree mark is calculated by adding 65% of the SS mark to a carry-forward of 35% of the JS mark.

Senior Sophister Theoretical Physics

The SS year consists of lectures, tutorials, attendance at the School Seminar series, and a research project. It is delivered in modules, as listed below. In their final year Theoretical Physics students also take taught modules in Mathematics. They take 20 mandatory credits of taught modules in Physics and up to 10 optional credits. They also take a 10 credit research project in either Physics or Mathematics. The balance is from taught modules in Mathematics, or Mathematics and a Broad Curriculum (BC) module.

Mandatory Taught Modules (20 credits):

PYU44P02 High Energy Physics – 5 credits
Hilary Term – 24 lectures/tutorials

PY4T01 Condensed Matter Theory – 5 credits
Michaelmas Term – 24 lectures/tutorials

PY4T03 Quantum Optics and Information – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44PP5 Problem-Solving– 5 credits
Michaelmas Term– Problem-Solving Tutorials and Seminars

Mandatory Project (10 credits):

PY4TP2 Research Project – 10 credits
OR MA4492 Project – 10 credits
Michaelmas Term, Hilary Term – Research project, meetings with supervisor by arrangement.

Optional Taught Modules (Choose up to 10 credits):

PYU44P04 Nanoscience – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44P07 Advanced Topics – 5 credits
Hilary Term – 24 lectures/tutorials – Students select 2 topics from the five offered.

PYU44A05 Cosmology – 5 credits
Hilary Term – 20 lectures/tutorials

PYU44C01 Computer Simulation III – 5 credits
Hilary Term – 24 lectures/tutorials

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

In order to pass the year and be awarded a Moderatorship degree every student must pass each module and gain an overall mark of at least 40%. The overall end-of-year mark and grade is calculated based on the credit-weighted average of the module marks (both Physics and Maths modules). If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module.

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

The problem-solving module PYU44PP5 is assessed by a 3-hour examination in the semester 1 examination period.

The balance of credits comes from Mathematics modules. The final degree mark in Theoretical Physics is calculated by adding 65% of the SS mark to a carry-forward of 35% of the JS mark.

Senior Sophister Physics and Astrophysics

The SS year consists of lectures, tutorials and practicals delivered in modules, as listed below. A major component of the practical module (PYU44PP2) is an independent research project, which is carried out during the first 9 weeks of Michaelmas term. There are no lectures during this period.

All modules are mandatory.

PYU44P01 Quantum Mechanics and High Energy Physics – 10 credits
Michaelmas/Hilary Term – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44A01 Cosmology, Planetary and Space Science – 10 credits
Michaelmas / Hilary Term – 44 lectures/tutorials

PYU44C01 Computer Simulation III – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44PP2 Physics Research Project – 20 credits
Michaelmas Term, Hilary Term – Research Project

PYU44PP5 Problem Solving in Physics – 5 credits
Michaelmas Term– Problem Solving Tutorials and Seminars

Further details including learning outcomes are given for all modules in the *Index of Modules* p 46ff.

Assessment and Examination Procedures

In order to pass the year and be awarded a Moderatorship degree every student must pass each module and gain an overall mark of at least 40%. The overall end-of-year mark and grade is calculated based on the credit-weighted average of the module marks. If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period. The 10-credit lecture modules PYU44P01 and PYU44A01 are examined in the examination period following semester 2. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

The problem-solving module PYU44PP5 is assessed by a 3-hour examination in the semester 1 examination period. The project PYU44PP2 is assessed during semester 2.

The final degree mark is calculated by adding 65% of the SS mark to a carry-forward of 35% of the JS mark.

Senior Sophister Nanoscience, Physics and Chemistry of Advanced Materials

Physics for Senior Sophister N-PCAM students consists of lectures, tutorials and practicals delivered in modules, as listed below. A major component of the practical module is an independent research project, which may be carried out at a facility off-campus.

All modules are mandatory.

PYU4PP03 Condensed Matter and Nanoscience – 10 credits
Michaelmas/Hilary Term – 48 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44P07 Advanced Topics in Physics – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44NP2 Physics Research Project – 20 credits
Michaelmas Term, Hilary Term – Research Project

PYU44NP5 Problem Solving in Physics – 5 credits
Michaelmas Term– Problem Solving Tutorials and Seminars

Assessment and Examination Procedures

In order to pass the year and be awarded a Moderatorship degree every student must pass each module and gain an overall mark of at least 40%. The overall end-of-year mark and grade is calculated based on the credit-weighted average of the module marks (both Physics and Chemistry modules). If a student does not achieve a pass grade in a module they must either compensate (p. 9) or take a supplemental exam in that module. Marks in the supplemental exams are calculated in the same way as in the end of semester exams.

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period. The 10-credit lecture module PYU44P03 is examined in the examination period following semester 2. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer 2 questions. In cases where the a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module.

If a 5-credit module is assessed partly by continuous assessment the number of exam questions offered and to be answered may vary. The details of the assessment are given in the *Index of Modules* (see p 46ff.)

The problem-solving module PYU44NP5 is assessed by a 3-hour examination with an essay in the semester 1 examination period. The project PYU44NP2 is assessed during semester 2.

The balance of credits comes from Chemistry modules. The final degree mark is calculated by adding 65% of the SS mark to a carry-forward of 35% of the JS mark.

General Guidelines

Grading criteria

Grades are distinguished as follows:

I	70% – 100%
II.I	60% – 69%
II.2	50% – 59%
III	40% – 49%
F1	30% – 39%
F2	0% – 29%

Study guidelines

The Study Skills Web Seminar (student-learning.tcd.ie/undergraduate/topics/study-skills) is an excellent site provided by the Student Counselling Service.

The aim of the Study Skills Web Seminar is to empower you to deal with the transition into third level education and with future changes in work situations.

There are dramatic changes as a result of moving into higher education in terms of the personal, social and financial aspects of your life. In terms of your learning, the biggest change is the need for you to take responsibility for your own learning. Courses in University demand more independent study and less contact time with teaching staff.

Timetables

Personalized timetables for each student are available on the student information system at my.tcd.ie.

Information on Academic Resources

Useful websites

College website: www.tcd.ie

School of Physics website: physics.tcd.ie

Library website: www.tcd.ie/library

Student Societies: www.trinitysocieties.ie

Student Services: www.tcd.ie/students

Library facilities

Hamilton Library, Hamilton Building
Opening hours (term time):
Mon – Fri: 09.30 – 22.00
Sat: 09.30 –16.00

Opening hours for all libraries can be found at www.tcd.ie/Library/opening-hours/

Physics Computer Room

The Physics computer lab has 30 PCs for use by Physics students, when not in use for classes. It is located on the ground floor of SNIAM, opposite the SNIAM conference room.

College Maps

Interactive maps of College campus can be found online at the link below. These include maps of facilities such as libraries, computer rooms, cafes and sports facilities.

www.tcd.ie/maps

Health and Safety

Health and Safety Induction and Health Declaration Forms

Junior Fresh Students

Junior Fresh students should complete the online Health and Safety Induction and Quiz using the Blackboard system before beginning any laboratory practical classes. This includes completion of the Health Declaration Forms.

School Safety Statement and Policy

Senior Sophister Students doing a Research Project

Before beginning an experimental research project, students must read the School safety statement, which can be found online at: www.tcd.ie/Physics/safety. Students must sign Appendices F and H of the safety statement and return them to the School Safety Officer.

Students who work with chemicals should pay particular attention to the chemicals section. Students who work with lasers must attend the laser safety seminar. General safety documents can be found online.

In the event of an emergency, dial Security Services on extension 1999 Security Services provide a 24-hour service to the college community, 365 days a year. They are the liaison to the Fire, Garda and Ambulance services and all staff and students are advised to always telephone extension 1999 (+353 1 896 1999) in case of an emergency.

Should you require any emergency or rescue services on campus, you must contact Security Services. This includes chemical spills, personal injury or first aid assistance.It is recommended that all students save at least one

School phone numbers relating to safety

Safety Officer	Mr. Joe McCauley	2218 (01-896 2218)
Chief Technical Officer	Mr. Kenneth Concannon	1308 (01-896 1308)
Chemical Safety	TBC	
Radiological Protection	TBC	
Laser Safety	Mr. Chris Smith	3649 (01-896 3649)
Electrical safety	Mr. Joe McCauley	2218 (01-896 2218)
First Aid	Mr. Joe McCauley Mr. Patrick Murphy Mr. Chris Smith	2218 (01-896 2218) 1219 (01-896 1219) 3649 (01-896 3649)

Student Supports

Student services make a crucial contribution to the student experience at Trinity College. The mission of student services is to provide opportunities of the highest quality for student development in an inclusive, caring and cost-effective way, consistent with the academic mission of College. Here is a list of the Student Services available in Trinity. You will find more information on each service's website.

Tutorial service

Trinity College assigns a tutor to each undergraduate student. Tutors are academic staff members who look after the welfare and development of a student in relation to their academic progress. They can advise on such matters as choosing courses, assessments and exams and act as an advocate in dealing with the university. She/he will be a source of help and guidance throughout your time as a student. See the Senior Tutor's website for further information.

Erasmus students have a co-ordinator whose function is similar to that of a tutor.

Student Counselling

The Student Counselling Service will help you to manage any difficulties you are experiencing so you can enjoy and fully participate during your time in College. It is a confidential and professional service that is available free of charge to every Trinity College student. It offers help in coping with any personal or emotional problems that may impact on your studies or progress in the University, and offers learning support and development aids. Visit the Student Counselling website to find out more about the services available, such as one-to-one sessions with a trained counsellor, group therapy and educational workshops, on-line support programmes, student-to-student support and more.

Learning Support and Development

On the Student Learning Support and Development Services' website (student-learning.tcd.ie/) you will find links to sites in College that can assist you with your learning support requirements.

Disability Service

The Disability Service provides supports for students with a disability or specific learning difficulty. Students requiring support in College are advised to contact the Disability Service as early as possible in order to register for examination accommodations, academic support and assistive technology.

The service is located in Room 2054 of the Arts Building, on the entrance level, past the Lecky Library. You will be assigned a Disability Officer who will work with you to assess the level of support you require.

Trinity College requires evidence of a disability from a Medical Consultant/Specialist to support the provision of any reasonable accommodations in College. Students with Specific Learning Difficulties (e.g. dyslexia) should provide a copy of their most recent Educational Psychology Report.

College Health Service

The College Health Service in House 47 is open every week day and provides inexpensive primary health and psychiatric care, by appointment. It is open Monday to Friday from 9.30 am to 4.40 pm.

Careers Advisory Service

What do you want to do? How will you get there? We are here to support you in answering these and other questions about your career.

Junior and Senior Fresh Students

Get Involved: Remember that your course of study, extra- curricular activities, voluntary and part-time work all provide opportunities for developing skills and gaining an insight into your career preferences. In your Senior Fresh year, look out for short-term internship opportunities.

MyCareer: Log in to MyCareer to keep abreast of jobs, study and careers events of interest to you.

Junior Sophisters

Attend class seminar: Typically this takes place in Hilary term and includes information on applying for work experience and internships and postgraduate study.

Get work experience: The programme of summer work experience and internships is particularly relevant to Junior Sophisters. Personalise your MyCareer profile to receive email alerts tailored to your preferences.

MyCareer: Log in to MyCareer to keep abreast of jobs, study and careers events of interest to you.

Finalists and Senior Sophisters

Meet Employers and/or Explore Further Study: You may have decided to seek employment directly after graduation and many employers visit Dublin to actively seek out talented graduates. For others, further study may be their preferred option. Your MyCareer dashboard will keep you informed.

Find Jobs: Personalise your MyCareer profile to receive email alerts tailored to your interests.

Attend class seminar: Typically this takes place in Michaelmas term and includes information on applying for postgraduate study and jobs.

GradLink Mentoring: An opportunity to get advice and support from a Trinity graduate.

Drop-In CV/ LinkedIn Clinics: We also provide support at a practical level, helping you to improve your applications, which will benefit you in securing your future, whether in employment or further study.

Practice Interviews: A practice interview tailored to the job/ course of your choice with practical feedback.

MyCareer: Log in to MyCareer to keep abreast of jobs, study and careers events of interest to you.

MyCareer

An online service that you can use to:

- Apply for opportunities which match your preferences - vacancies including research options
- Search opportunities- postgraduate courses and funding
- View and book onto employer and CAS events
- Submit your career queries to the CAS team
- Book an appointment with your Careers Consultant

Simply login to MyCareer using your Trinity username and password and personalise your profile.

Careers Advisory Service

Trinity College Dublin, 7-9 South Leinster Street, Dublin 2

01 896 1705/1721 | Submit a career query through MyCareer

MyCareer: mycareerconnect.tcd.ie

TCD.Careers.Service

TCDCareers

www.tcd.ie/Careers/students/postgraduate/

@TCDCareers

tinyurl.com/LinkedIn-TCD-Connecting

Opening Hours

During term: 9.30am - 5.00pm, Monday - Friday

Out of Term: 9.30am - 12.30pm & 2.15 - 5.00pm, Monday - Friday

Information Technology Services

Information Technology Services (IT Services) is responsible for the provision and support of computer systems, networking, and audio-visual and media services in College.

During Freshers' Week it is well worth investing some time in finding out about the range of IT services that you can use as a TCD student. Once you have registered and obtained your computer username and password, you are invited to attend an IT induction session where you can find out about the services available to students. Topics covered include activating your TCD e-mail account, using the College Computer Rooms and College printing system, and accessing your timetable online. Also, if you own a computer, you'll find out about what's involved in bringing it into College, registering to use it on the College network and availing of College's Wi-Fi service.

Sports

Trinity College recognizes the important role that sport plays in a well-rounded university education and has a full range of sports facilities both on and off campus. All students are encouraged to participate. The Sports Centre has a 25-metre, 6-lane swimming pool, a large fitness theatre with over 60 exercise stations, an 11-metre-high climbing wall, a fitness studio, a spin studio, a sauna and steam room, and two large sports halls.

There are 50 sports clubs in Trinity College so no matter what your sporting preference you will find a club to suit you with options such as rugby, soccer, hockey, swimming, tennis, Gaelic games, basketball, volleyball, cricket and martial arts. Off-campus there are extensive playing fields at Santry, and the Trinity Boat Club has its boathouse on the River Liffey at Islandbridge.

Student Societies

There are societies like the Philosophical Society and the College Historical Society with their established debating tradition and impressive guest speakers, such as Pete Doherty, John C. Reilly, Robert Fisk and Archbishop Desmond Tutu. Others, like the Filmmakers Society, Trinity FM, the Trinity Arts Workshop and the Photography Society, have their own studios on campus and hold regular screenings, broadcast weeks, exhibitions and classes, respectively. You can try your hand at everything from acting to archaeology, politics to paintballing, and singing to scifi. You can relax with the Yoga society or de-stress in a different way with the Comedy Society or the Food and Drink society. And if you don't find a society that interests you, you can always set one up yourself!

DU PhySoc

The Dublin University Physical Society is a student society dedicated to physics and fun. Traditionally these two words do not often appear in the same sentence, and some say that this is why the society exists! More formally, two of the core aims of the society (as stated in its constitution) are:

- To encourage the study of physics by members of the University
- To raise the standards of awareness of physics and its benefits among the community at large

The PhySoc provides a recreational outlet for everyone in the School of Physics, hosting events that are excellent opportunities for both students and staff to interact in a social environment. While everyone in the School of Physics is encouraged to join PhySoc, it attracts members from all areas of College. Anyone with even a passing interest in physics is welcome, and most of the talks are intended for a general audience. The PhySoc hosts receptions, quizzes, blood drives, movie nights, football matches, tournaments and themed parties along with both local and overseas trips - to name but a few of the activities. If you have any specific questions about DU PhySoc contact duphysoc@gmail.com.

Index of Modules

PY1T10 Physics for Theoretical Physics
Michaelmas Term – lectures, practical laboratory, online & small group tutorials – 10 credits
(N Caffrey, L Bradley, M Möbius)

Introduction to Physics – 1 lecture
Special Relativity – 15 lectures
Waves and Optics I – 20 lectures
Statistics – 10 lectures

Learning Outcomes
On successful completion of this module, students should be able to:
- Express relativistic effects concerning the motion of a body, as observed in different inertial reference frames
- Describe wave motion and relate it to basic phenomena in light and sound
- Understand sources of errors in measurements and calculate their propagation.
- Prepare a brief report, including error analysis, on a simple physical experiment

Syllabus
What is Physics – 1 lecture
An introduction to the School of Physics and the JF Physics course.

Special Relativity – 15 lectures
Galilean transformations, Michelson-Morley experiment. Lorentz transformations, time dilation, length contraction, simultaneity. Doppler effect. Transformation of velocities and forces. Relativistic dynamics. Pair creation, fission, fusion. Collisions. Compton effect. Relativity and electromagnetism.

Waves and Optics I – 20 lectures
Resonance, harmonic oscillators, SHM, frequency.
Waves: standing, travelling, wavelength, wave velocity.
Sound: music, vibrations of a string and of a column of air, harmonics, Doppler effect.
Light: Rayleigh scattering, refraction, reflection, dispersion, index of refraction, polarization, polarized reflection, Malus' law, birefringence, total internal reflection, colour vision, gas discharges, lasers.
Optics: refracting optics, lenses, real images, focus, focal length,
f-numbers, lens equation, cameras, reflecting optics, curved mirrors, telescopes.
Interference: superposition of waves, beating, 2 beam interference, anti-reflection coating.
Diffraction: Huygen's principle, diffraction by a slit and grating, X-ray diffraction.

Statistics – 10 lectures
Systematic and random errors. Discrete and continuous distributions such as binomial, Poisson, Gaussian and Lorentzian. Moments of a distribution. Histograms and probability densities. Estimation of mean and standard deviation in a measurement. Error propagation and transformation of variables in probability distributions. Linear regression analysis, method of least squares, goodness of fit (Chi squared) and plotting techniques. Introduction to programming basics in Python.

Assessment	**Weighting**
Examination	60%
Laboratory Practical work	30%
Online tutorials	10%

PY1T20 Physics for Theoretical Physics

Hilary Term – lectures, practical laboratory, online & small group tutorials – 10 credits
(J Groh, P. Eastham, A. Vidotto)

Electricity and Magnetism I – 20 lectures
Quantum Physics – 18 lectures
Gravitation and Astrophysics – 12 lectures

Learning Outcomes

On successful completion of this module, students should be able to:

- Solve steady state time-varying electric current and electric potential problems
- Solve electrostatic problems using Gaussian Surfaces
- Show an understanding of the principles and origins of quantum mechanics, and its role in the physics of matter and radiation.
- Solve elementary problems in quantum mechanics
- Develop the ideas of Newton's Law of Gravitation, with an emphasis on it being an inverse-square law
- Describe observational insights into the structure and evolution of the universe.

Syllabus

Electricity and Magnetism I– 20 lectures
Electrostatics: electric charge, Coulomb's law, electric field, electric dipoles, Gauss's law, electric potential energy, voltage, electric polarization, capacitance, dielectrics, Electric current, resistance, Ohm's law, electromotive force, power in electric circuits, Kirchoff's laws, RC circuits. Magnetism, magnetic field lines and flux; Lorentz force on moving charge; Energy of and torque on a current loop in a magnetic field; Biot-Savart Law illustrated by magnetic fields of a straight wire and circular loop; forces between current-carrying straight wires; Ampere's Law in integral form.

Quantum Physics – 18 lectures
Origins of quantum physics. Photoelectric effect. Compton Effect. De Broglie's Postulate. The Uncertainty Principle. Black body radiation and specific heat. Atomic spectra. Bohr model of the atom. Correspondence Principle. Steady-state Schrödinger equation. Particle in a 1-D box. Finite potential well. Simple harmonic oscillator. Particle at potential step. Tunnelling through a barrier. Angular momentum and spin. Quantum theory of Hydrogen atom. The periodic table. Formation of chemical bonds. Quantum information.

Gravitation and Astrophysics – 12 lectures
Motion of the planets: early models of the solar system, Newton's law of gravitation, gravitational potential energy, motion of satellites, Kepler's laws and the motion of planets (derivation of the orbit equation, conservation of angular momentum, properties of the ellipse), apparent weight and the earth's rotation, escape velocity. Our solar system - the planets: physical properties, composition, terrestrial planets, gas giants. Extrasolar planets: detection methods. Observing the universe: refracting telescopes, reflecting telescopes, space telescopes, radio observations. The Sun: physical properties, solar interior, solar surface and atmosphere. Stars: constellations, magnitudes, distances, size of stars, the Hertzprung-Russell Diagram, introduction to stellar evolution. Galaxies: the Milky Way, other galaxies, dark matter. Origin and evolution of the universe: the expansion of the universe, age of the universe, big bang models, cosmic microwave background.

Assessment	**Weighting**
Examination	60%
Laboratory Practical work	30%
Online tutorials	10%

PYU22P10 Classical Physics

PY2T10 Classical Physics for Theoretical Physics

Michaelmas Term – lectures, practical laboratory, project, small group tutorials – 10 credits
(G Cross, H Zhang, S Dooley, M Hegner)

This module combines elements of classical physics, as follows:

Thermodynamics – 15 lectures
Electricity and Magnetism II – 14 lectures
Oscillations – 12 lectures
Materials – 12 lectures

Learning Outcomes

On successful completion of this module, students should be able to:

- Solve basic problems in relation to harmonic oscillators
- Relate the concept of oscillations to optical properties of matter and AC circuits
- Describe elementary crystal structures and the response of materials to external forces
- Employ web-based research techniques in a small group project and present the results in the form of a poster
- Prepare a report detailing methodology, data gathering and interpretation of a physical experiment
- Describe how the laws of thermodynamics react to properties of matter

Syllabus

Thermodynamics – 15 lectures
Kinetic theory and the ideal gas equation. Van der Waals model for real gases. First law of thermodynamics. Internal energy, heat and work. Reversible and irreversible processes. Specific heat. Second law of thermodynamics. Heat engines, Carnot cycles. Entropy. Probability and disorder. Combined first and second laws. Central equation. H, F, G. Maxwell's relations. Energy equations. Cooling processes. Joule-Kelvin effect. Third law of thermodynamics.

Electricity and Magnetism II – 14 lectures
Magnetism, magnetic field lines and flux; Lorentz force on moving charge; Energy of and torque on a current loop in a magnetic field; magnetic fields of moving charges; Biot-Savart Law illustrated by magnetic fields of a straight wire and circular loop; forces between current-carrying straight wires; Ampere's Law in integral form illustrated by field of a straight conductor of finite thickness. Electromagnetic induction and Faraday's Law in integral form; Lenz's Law; induced electric fields and motional emf's; summary of Maxwell equations in integral form; Mutual inductance and self-inductance. R-L circuits and L-R-C circuits. AC circuits, phasor diagrams, reactance, resonance, transformers and complex representation of reactance. Power analysis. R-C integration and differentiation, R-C low- and high-pass filters and active filters.

Materials – 12 lectures
Inter- and intra- molecular forces, potential energy curves, heat capacity, thermal expansion and conductivity. Stress, strain, shear, elastic and plastic deformations of solids. Structures of solids in crystalline, glass, plastic phases. Insulators, conductors and semiconductors. Point defects and imperfections in solids – Iron/Carbon system. Density, pressure, surface tension, buoyancy and hydrodynamic-incompressible and compressible flows in fluids. Bernoulli's equation. Viscosity,

diffusion, laminar and turbulent flow. Gas laws, kinetic theory and collisions, PVT diagrams, thermal expansion. Conductive, convective and radiative transport of heat. Stefan-Boltzmann law.

Oscillations – 12 lectures

Review of simple harmonic motion. Forced and damped oscillations. Resonance. Two coupled oscillators, modes and normal coordinates. Many coupled oscillators. Transition to continuous systems. Waves. Nonlinear behaviour. Anharmonic behaviour.

Assessment	**Weighting**
Examination	60%
Experimental / Computational laboratories	25%
Project	5%
Tutorials	10%

PYU22N20 Modern Physics and Materials

Hilary Term – lectures, practical laboratory, small group tutorials – 10 credits
(C Patterson, M Stamenova, P Stamenov, D McCloskey)

This module combines three elements of modern physics and an introduction to materials, as follows:

Special Relativity – 12 lectures
Nuclear and Particle Physics – 14 lectures
Materials Properties and Phase Diagrams – 12 lectures
Waves and Optics II – 14 lectures

Learning Outcomes
On successful completion of this module, students should be able to:

- Describe how modern physics is underpinned by nuclear and particle physics; waves and optics
- Express relativistic effects as observed in different inertial reference frames
- Relate the preparation of materials to the resulting microscopic structure and material properties, based on the interpretation of phase diagrams
- Analyse, modify and run Python language programs to perform computer experiments
- Obtain, pre-process, display and analyse experimental data using software packages such as Origin

Syllabus

Special Relativity – 12 lectures
Frames of reference and relativity principles. The Michelson-Morley experiment. Einstein's postulates, simultaneity, the Lorentz transformation, the Fitzgerald-Lorentz contraction, time dilation, transformation of velocities. Relativistic dynamics – mass, energy and momentum.

Nuclear and Particle Physics – 14 lectures
Models of the atom. Rutherford scattering. Cross-sections. Nucleons. Nuclear force. Nuclear binding. Nuclear masses. Mass defect. Mass dependence of binding energy per nucleon. Beta decay. Electron, positron emission. Electron capture. Decay chains. Alpha decay. Heavy element decay chains. Barrier penetration mechanism. Gamma decay. Radioactive decay law. Analysis of parent-daughter activity relationships. Nuclear fission. Liquid drop model. Fission products. Induced fission. Nuclear reactors. Neutron moderation. Control and delayed neutrons. Reactor types. Environmental and other concerns. Fuel cycle. Nuclear fusion. Fusion reactors. Fundamental particles, Leptons and Baryons, Quarks.

Materials Properties and Phase Diagrams – 12 lectures
Mechanical properties of materials: Stress, strain, elastic and plastic deformation. The concepts of dislocations and strengthening mechanisms. Failure: fracture, fatigue and creep. Phase diagrams: The aim of this course is to introduce Liquid-Solid equilibria and to understand how a phase diagram is constructed and what information can be extracted from it. A direct application will be the study of the Fe-C system. Binary phase diagram, two phase equilibria (solubility / solid solution, lever rule), three phase equilibria (formation of compounds, eutectic), ternary phase diagram, application to the Fe-C system. Applications and examples are tuned mostly towards metals, semiconductors and ceramic materials. Methods for studying other structural and physical properties are also discussed briefly, with examples of x-ray and electron scattering, electronic and heat transport amongst others.

Waves and Optics II – 14 lectures
Maxwell equations in differential form. Coulomb's and Gauss' Laws; Biot-Savart and Ampere's Laws; absence of magnetic monopoles; Faraday's Law and magnetic induction. Electric dipoles, dielectric polarisation and dielectric susceptibility; magnetic dipoles, magnetisation and diamagnetic susceptibility; continuity equation, displacement current and Maxwell's generalisation of Ampere's Law. Electromagnetic waves in vacuum and isotropic matter. Energy density in time-varying electromagnetic fields and Poynting vector. Reflection, refraction, plane, circular and elliptic polarisation of light; dichroism, birefringence; interference, interferometers, coherence, Young's slits, near and far field diffraction.

Assessment	**Weighting**
Examination	60%
Experimental / Computational laboratories	30%
Tutorial	10%

PYU22P20 Modern Physics

Hilary Term – lectures, practical laboratory, small group tutorials – 10 credits
(C Patterson, M Stamenova, A Vidotto, D McCloskey)

This module combines four elements of modern physics, as follows:
Special Relativity – 12 lectures
Nuclear and Particle Physics – 14 lectures
Astrophysics – 12 lectures
Waves and Optics II – 14 lectures

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe how modern physics is underpinned by nuclear and particle physics; waves and optics
- Express relativistic effects as observed in different inertial reference frames
- Explain a broad variety of astrophysical phenomena with simple physics
- Prepare calculations and present in small groups
- Analyse, modify and run Python language programs to perform computer experiments
- Obtain, pre-process, display and analyse (fit to analytical models) actual experimental data using software packages such as Origin

Syllabus

Special Relativity – 12 lectures

Frames of reference and relativity principles. The Michelson-Morley experiment. Einstein's postulates, simultaneity, the Lorentz transformation, the Fitzgerald-Lorentz contraction, time dilation, transformation of velocities. Relativistic dynamics – mass, energy and momentum.

Nuclear and Particle Physics – 14 lectures

Scattering. Cross-sections. Rutherford scattering. Nuclear force. Nuclear binding. Nuclear masses. Mass defect. Mass dependence of binding energy per nucleon. Beta decay. Electron, positron emission. Electron capture. Decay chains. Alpha decay. Heavy element decay chains. Barrier penetration mechanism. Gamma decay. Radioactive decay law. Analysis of parent-daughter activity relationships. Nuclear fission. Liquid drop model. Fission products. Induced fission. Nuclear reactors. Neutron moderation. Control and delayed neutrons. Reactor types. Environmental and other concerns. Fuel cycle. Nuclear fusion. Fusion reactors. Fundamental particles, Leptons and Baryons, Quarks.

Astrophysics – 12 lectures

Continuous radiation of stars: flux, luminosity, magnitudes, colours. Spectral lines in stars: spectral classification, origin of spectral lines, the Hertzprung-Russell diagram. Binary stars: Doppler effect in astronomy, stellar masses, mass-luminosity-radius relationship. Basic nucleosynthesis and stellar equilibrium. Life and death of stars: stellar evolution, end stages of stellar evolution, planetary nebulae, white dwarfs, supernovae, neutron stars and black holes. Interstellar medium. Star formation: gravitational collapse, initial mass function. Exoplanets and life in the Universe: planet formation, exoplanets detection and statistics, life in the universe. Galaxies and galaxy clusters: Milk Way, galactic rotation, dark matter, galaxy classification, distribution of galaxies, expansion of the Universe, galaxy clusters, active galaxies. Cosmology and the early Universe: gravitational lensing, cosmology, the evolution of the universe, dark energy, big bang theory.

Waves and Optics II – 14 lectures

Maxwell equations in differential form. Coulomb's and Gauss' Laws; Biot-Savart and Ampere's Laws; absence of magnetic monopoles; Faraday’s Law and magnetic induction. Electric dipoles, dielectric polarisation and dielectric susceptibility; magnetic dipoles, magnetisation and diamagnetic susceptibility; continuity equation, displacement current and Maxwell's generalisation of Ampere's Law. Electromagnetic waves in vacuum and isotropic matter. Energy density in time-varying electromagnetic fields and Poynting vector. Reflection, refraction, plane, circular and elliptic polarisation of light; dichroism, birefringence; interference, interferometers, coherence, Young's slits, near and far field diffraction.

Assessment	**Weighting**
Examination	60%
Experimental / Computational laboratories	30%
Tutorials	10%

PY2P30 Physics for Earth Sciences

Michaelmas Term – 24 lectures/tutorials, practical laboratory and homework – 5 credits (S Murray, C McGuinness, N Carroll)

The aim of this module is to provide an introduction to the application of physical principles in the study of earth science. The module will be taught through a combination of lectures, laboratory classes and tutorials.

Learning Outcomes

On successful completion of this module student will be able to:

- Apply Newtonian mechanics to the description of gravitational attraction, planetary motion and origin of tides and effect of Coriolis force in atmospheric circulation.
- Apply principles of statics to describe bodies in equilibrium, elasticity and fracture.
- Understand and calculate hydrostatic pressure, buoyancy and flow in fluid systems.
- Understand the mechanical analysis of seismic and water waves, including calculation of wave velocity, reflection and refraction.
- Understand the concepts of heat and temperature and elementary thermodynamics.
- Describe and calculate adiabatic processes in the Earth’s atmosphere, including the effects due to water vapour.
- Describe and do calculations involving radiative transfer and energy balance in the Earth’s atmosphere.
- Make measurements on a physical system, analyse the results and prepare a report.

Syllabus

Gravitational attraction, planetary motion, origin of tides, Coriolis force, statics, elasticity and fracture, hydrostatic pressure, buoyancy and flow in fluid systems, seismic and water waves, composition and structure of Earth's atmosphere, elementary thermodynamics, adiabatic processes in atmosphere, cloud formation leading to rain, radiative energy transfer and energy balance in Earth's atmosphere.

Assessment	**Weighting**
Examination	60%
Experimental laboratory	30%
Homework	10%

PY2T20 Modern Physics for Theoretical Physics

Hilary Term – lectures, practical laboratory, small group tutorials – 10 credits (S Hutzler, M Stamenova, A Vidotto, D McCloskey)

This module combines four elements of modern physics, as follows:

Chaos and Complexity – 12 lectures
Nuclear and Particle Physics – 14 lectures
Astrophysics – 12 lectures
Waves and Optics II – 14 lectures

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe how physics is underpinned by quantum and nuclear physics; waves and optics
- Explain the concepts of deterministic chaos and complexity in relation to dynamical systems
- Explain a broad variety of astrophysical phenomena with simple physics
- Prepare calculations and present in small groups
- Write and run Python programs to perform computer experiments

Syllabus

Chaos and Complexity – 12 lectures
Examples of chaotic systems, logistic map, period doubling, Feigenbaum numbers, Ljapunov exponent, phase portraits, iterated maps, fractals, self organised criticality, cellular automata, dynamics of pedestrian motion.

Nuclear and Particle Physics – 14 lectures
Scattering. Cross-sections. Rutherford scattering. Nuclear force. Nuclear binding. Nuclear masses. Mass defect. Mass dependence of binding energy per nucleon. Beta decay. Electron, positron emission. Electron capture. Decay chains. Alpha decay. Heavy element decay chains. Barrier penetration mechanism. Gamma decay. Radioactive decay law. Analysis of parent-daughter activity relationships. Nuclear fission. Liquid drop model. Fission products. Induced fission. Nuclear reactors. Neutron moderation. Control and delayed neutrons. Reactor types. Environmental and other concerns. Fuel cycle. Nuclear fusion. Fusion reactors. Fundamental particles, Leptons and Baryons, Quarks.

Observing the Universe – 12 lectures
Continuous radiation of stars: flux, luminosity, magnitudes, colours. Spectral lines in stars: spectral classification, origin of spectral lines, the Hertzprung-Russell diagram. Binary stars: Doppler effect in astronomy, stellar masses, mass-luminosity-radius relationship. Basic nucleosynthesis and stellar equilibrium. Life and death of stars: stellar evolution, end stages of stellar evolution, planetary nebulae, white dwarfs, supernovae, neutron stars and black holes. Interstellar medium. Star formation: gravitational collapse, initial mass function. Exoplanets and life in the Universe: planet formation, exoplanets detection and statistics, life in the universe. Galaxies and galaxy clusters: Milk Way, galactic rotation, dark matter, galaxy classification, distribution of galaxies, expansion of the Universe, galaxy clusters, active galaxies. Cosmology and the early Universe: gravitational lensing, cosmology, the evolution of the universe, dark energy, big bang theory.

Waves and Optics II – 14 lectures
Maxwell equations in differential form. Coulomb's and Gauss' Laws; Biot-Savart and Ampere's Laws; absence of magnetic monopoles; Faraday’s Law and magnetic induction. Electric dipoles, dielectric polarisation and dielectric susceptibility; magnetic dipoles, magnetisation and diamagnetic susceptibility; continuity equation, displacement current and Maxwell’s generalisation of Ampere’s

Law. Electromagnetic waves in vacuum and isotropic matter. Energy density in time-varying electromagnetic fields and Poynting vector. Reflection, refraction, plane, circular and elliptic polarisation of light; dichroism, birefringence; interference, interferometers, coherence, Young's slits, near and far field diffraction.

Assessment	**Weighting**
Examination	60%
Experimental / Computational laboratories	30%
Tutorials	10%

PYU33A03 Stellar and Galactic Structure

Michaelmas Term – 30 lectures/tutorials – 5 credits (J Groh)

Part I: Stellar Astrophysics
Part II: Galaxies: From the Milky Way to Quasars

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe the major stages in the evolution of a star from birth to death
- Explain the Hertzsprung-Russell diagram for stellar populations of different ages
- Manipulate the basic equations for stellar structure and evolution in order to derive elementary results for global stellar properties and timescales
- Derive the basic equations governing the dynamics of the Sun and nearby stars with respect to the Galaxy
- Explain the distribution of stars, gas and dust within galaxies, and describe the properties of the various types of galaxies found in the Universe
- Discuss the evidence for massive black holes at the centres of active galaxies and for Dark Matter in the Universe on a variety of scales

Syllabus

Part I: Stellar Astrophysics

The structure of a star is regulated by the balance between gravity and pressure, and is almost entirely governed by its mass and chemical composition.
We discuss the physics of stellar material, including the equation of state and radiative opacity, as well as major energy transport processes. A star's evolution is dictated by nuclear reactions which produce heat and transform chemical structure. We explore how stars evolve from clouds of interstellar gas to become main-sequence stars like the Sun, and then expand to become red giants and helium-burning stars. We examine the final stages of stellar evolution, including white dwarfs, supernovae and neutron stars. The use of binary stars and pulsations for testing the stellar structure theory will be demonstrated.

Part II: Galaxies: From the Milky Way to Quasars

Gravitational forces determine the movements of the stars within a galaxy. Several aspects of this basic problem will be considered, such as space distribution of stars, stellar velocity distribution, high-velocity stars, rotation curve of stellar systems, integrals of motion, individual stellar orbits. The stars moving around in elliptical galaxies exhibit triaxial velocity ellipsoids, while the ordered motion in disk systems gives rise to spiral density patterns. The stellar movements indicate that large amounts of unseen mass may be associated with galaxies and with clusters of galaxies. Many details of stellar dynamics become evident in the close surroundings of our own Galaxy where a large body of observational data assists our understanding.

Assessment	**Weighting**
Examination	85%
Continuous Assessment in Galaxies: From the Milky Way to Quasars	15%

PYU33A06 Statistical Thermodynamics and Astrophysical Spectroscopy

Michaelmas Term – 30 lectures/tutorials – 5 credits (G Cross, B Espey)

Part I: Statistical Thermodynamics
Part II: Astrophysical Spectroscopy

Learning Outcomes
On successful completion of this module, students should be able to:
- Outline the basic concepts of equilibrium statistical thermodynamics
- Describe mathematically the behaviour of physical systems governed by Fermi-Dirac, Bose-Einstein, and Maxwell-Boltzmann statistics
- Determine the partition functions of simple quantum systems
- Distinguish between thermodynamic equilibrium (TE), local thermodynamic equilibrium (LTE), & non-LTE, and how these apply in the case of stellar interiors and surfaces
- Describe the basic phases of the curve-of-growth and illustrate the appearance of the line profiles associated with each stage
- Interpret the multi-dimensional stellar classification system with reference to the Saha and Boltzmann equations

Syllabus

Part I: Statistical Thermodynamics
The purpose of this course is to introduce Statistical Thermodynamics, which provides a microscopic understanding of the macroscopic thermodynamic properties of materials. A simple assumption of equal statistical weights allows the properties of individual quantum particles to be combined together properly to calculate macroscopic thermodynamic quantities, which can be compared with experiment. Topics covered (1) Counting states in classical and quantum systems (2) Fundamental assumption of statistical physics; ensembles (3) Model system of 2-state components (4) Two systems in equilibrium: entropy, temperature and chemical potential (5) Partition functions and their relation to thermodynamic quantities (6) Third Law of Thermodynamics (7) Fermi-Dirac and Bose-Einstein Statistics (8) Quasi-classical statistics: equipartition of energy (9) Application of quantum statistics to photons, gases, and solids.

Part II: Astrophysical Spectroscopy
Spectroscopy across the full EM spectrum is the primary means for determining the properties and characteristics of astronomical objects. Some important parameters which characterize astronomical spectra, and which determine the choice of instrumentation are reviewed, with a brief outline of some examples, focussing on the optical and ultraviolet portions of the spectrum. The underlying physics required for the interpretation of stellar spectra for stellar classification and for the diagnostics of low density plasmas is discussed and applied to some specific, topical examples.

Assessment	**Weighting**
Statistical Thermodynamics examination	50%
Astrophysical Spectroscopy examination	40%
Astrophysical Spectroscopy Continuous Assessment	10%

PYU33A07 Experimental Techniques for Astrophysics

Hilary Term – 30 lectures/tutorials – 5 credits (J McCauley, B Espey)

Part I: Electronics
Part II: Astrophysical instrumentation

Learning Outcomes

On successful completion of this module, students should be able to:

- Correctly identify the wavebands or passbands used for astronomical observations
- Give an overview of different types of telescopes and detection techniques for a range of electromagnetic and particle spectra
- Describe the processes that limit the angular resolution and sensitivity of telescopes and techniques used to overcome them
- Design basic circuits' power supply, communications and computer-interfacing
- Apply bandwidth-narrowing techniques to improve the signal-to-noise ratio in measurements
- Select imaging detectors for a given application, with regard to resolution, sensitivity and wavelength

Syllabus

Part I: Electronics

Electronic components. Power supplies. Computers and interfacing. Sensors and transducers. Control systems. Noise in electronic systems.

Part II: Astrophysical instrumentation

Telescopes and optical instrumentation. Observational limitations, aberrations, the effects of the atmosphere. Active and adaptive optics. New technology telescopes. Optical detection techniques. Optical interferometry. Basic concepts of radio astronomy. Receiver systems and detectors. Radio interferometry. Overview of different types of telescopes and detection techniques for other parts of the electromagnetic spectrum: infrared, ultraviolet, x-rays and gamma-rays

Assessment	**Weighting**
Examination – Exam in Electronics	50%
Examination – Exam in Astrophysical Instrumentation	40%
Continuous Assessment in Astrophysical Instrumentation	10%

PYU33AP1 Practical in Physics and Astrophysics

Michaelmas Term, Hilary Term – 20 credits (B Espey, A Vidotto, J Groh)

Part I: Practical Laboratory – 15 experimental laboratory sessions (of 4 hours duration) and 7 computational laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 18 lectures/workshops
Part III: School Seminars – 8 seminars

Learning Outcomes
On successful completion of this module, students should be able to:

- Operate advanced apparatus from manual instruction
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment
- Apply astrophysics computer methods
- Write a précis of a research seminar
- Make a scientific presentation to an audience
- Create a personal CV

Syllabus

Part I: Practical Laboratory – 15 experimental laboratory sessions (of 4 hours duration) and 10 computational laboratory sessions (of 6 hours each).

Part II: Communication Skills – 18 lectures/workshops Effective communication of scientific results and ideas as written reports and oral presentations. The structure of a scientific article. The role of graphics and diagrams. Style and vocabulary. Addressing an audience. Use of slides and overheads. Class members will give a short seminar to the entire JS lab group and write an essay on topical issues in physics.

Part III: School Seminars – 8 seminars

Assessment	**Weighting**
Assessment – Laboratory practical work	50%
Assessment – Computational laboratory practical work	40%
Assessment – Careers workshops and seminars	10%

PYU33AP2 Practical in Physics and Astrophysics (with Broad Curriculum module)

Michaelmas Term, Hilary Term – 15 credits (B Espey, A Vidotto, J Groh)

Part I: Practical Laboratory – 9 experimental laboratory sessions (of 4 hours duration) and 7 computational laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 18 lectures/workshops
Part III: School Seminars – 8 seminars

Learning Outcomes
On successful completion of this module, students should be able to:

- Operate advanced apparatus from manual instruction
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment
- Apply astrophysics computer methods
- Write a précis of a research seminar
- Make a scientific presentation to an audience
- Create a personal CV

Syllabus

Part I: Practical Laboratory – 9 experimental laboratory sessions (of 4 hours duration) and 7 computational laboratory sessions (of 6 hours each).

Part II: Communication Skills – 18 lectures/workshops Effective communication of scientific results and ideas as written reports and oral presentations. The structure of a scientific article. The role of graphics and diagrams. Style and vocabulary. Addressing an audience. Use of slides and overheads. Class members will give a short seminar to the entire JS lab group and write an essay on topical issues in physics.

Part III: School Seminars – 8 seminars

Assessment	**Weighting**
Assessment – Laboratory practical work	40%
Assessment – Computational laboratory practical work	50%
Assessment – Careers workshops and seminars	10%

PYU33C01 – Computer Simulation I

Michaelmas Term – 30 lectures/tutorials – 5 credits (S Hutzler, S. Power)

Part I: Numerical Methods I
Part II: Computational Methods

Learning Outcomes
On successful completion of this module, students should be able to:
- Apply standard numerical methods to problems of differentiation, integration and data handling
- Compute numerical solutions to ordinary differential equations
- Critically assess the application of Monte Carlo methods to minimization problems
- Explain the concept of genetic algorithms
- Use common Linux commands for file handling and data processing
- Perform computational tasks in Python using both scripts and interactive notebooks
- Import and call relevant functions from a variety of scientific computing libraries
- Prepare publication quality figures from numerical data

Syllabus

Part I: Numerical Methods I
Numerical differentiation/integration, solving ordinary differential equations, random numbers, Monte Carlo methods, genetic algorithms and neural networks.

Part II: Computational Methods
Introduction to Linux: command line, shell scripts and data processing. Programming in Python: syntax, scripts, notebooks and data structures. Scientific libraries: importing external packages; common modules for arrays, numerics and plotting (Numpy, SciPy, Matplotlib). Applications to physical problems. Advanced topics.

Assessment	**Weighting**
Continuous Assessment in Numerical Methods	50%
Continuous Assessment in Computational Methods	50%

PYU33P01 Quantum Mechanics I

Michaelmas Term – 30 lectures/tutorials – 5 credits (M Ferreira)

Learning Outcomes

On successful completion of this module, students should be able to:

- Recognize the need to extend the concepts developed in classical Physics to account for what happens with matter at the atomic and sub-atomic levels
- Identify when a problem requires the use of quantum-mechanics concepts and when it can be solved by standard classical theories
- Operate with the mathematical structure of quantum mechanics, in particular, linear algebra and wave mechanics
- Solve basic problems of Quantum Mechanics with regards to how a quantum particle behaves under the action of a few simple force potentials
- Apply perturbation theory to describe more complex and realistic systems in terms of those simple force potentials

Syllabus

Mathematical foundations of quantum mechanics: description of quantum states and dynamical variables, eigenvalue equations, superposition principle, expectation values. Solution of Schrödinger equation for 1-dimensional systems: SHO using ladder operators, Kronig-Penney model. Angular momentum: calculation of spectrum using ladder operators, orbital angular momentum and parity, spin. Solution of Schrödinger equation in 3 dimensions: the hydrogen spectrum. Time independent perturbation theory.

Assessment	**Weighting**
Examination	90%
Assessments	10%

PYU33P02 Electromagnetic Interactions I

Hilary Term – 30 Lectures – 5 credits (D O'Regan, W Blau)

Part I: Electromagnetic Theory
Part II: Quantum Optics & Lasers

Learning Outcomes

On successful completion of this module, students should be able to:

- Connect Maxwell's Equations with the equivalent experimental laws
- Distinguish between polar and non-polar electric media and, by analogy, the different magnetic media
- Apply Maxwell's Equations to the prediction of electromagnetic waves
- Explain when classical optics gives way to quantum optics
- Describe the operation of a laser in terms of population inversion and optical feedback
- Distinguish between spontaneous and stimulated emission, coherent and incoherent radiation, longitudinal mode and transverse modes
- Connect the laser properties of coherence and high brightness with applications in research, materials processing and communication

Syllabus

Part I: Electromagnetic Theory

Vector operators, Divergence and Stokes' theorems; Coulomb's and Gauss' Laws; dipoles and polarisation; electric susceptibility and displacement vector; polar dielectrics and Langevin analysis; potential and electric energy density; electrostatic boundary conditions and method of images; Biot-Savart and Ampere's Laws; magnetic dipole and magnetisation; H vector; vector potential; magnetic energy density; magnetostatic boundary conditions; dia, para and ferro magnetism; Faraday's law of electromagnetic induction; magnetoelectric induction; Maxwell's equations; plane waves; Poynting vector.

Part II: Quantum Optics & Lasers

Interaction of light with matter: black body radiation, the photoelectric effect, Einstein A and B coefficients. Light as photons. Coherence and fluctuations of real sources, correlation functions, photon statistics. Behaviour of photons in beam splitters, interferometers and cavities. The Raman effect. Basic laser theory: absorption and gain cross-section, saturation of absorption and gain, cavity lifetime and longitudinal modes, transverse mode structure, Gaussian beams. Three and four level lasers and power output in continuous wave lasers. Transient laser behaviour, relaxation oscillations, Q-switching, methods of Q-switching, mode-locking and methods of mode-locking. Specific laser systems: ruby and Nd-YAG/glass lasers, He-Ne laser, argon-ion laser, carbon-dioxide laser, excimer laser, dye laser and semiconductor diode laser.

Assessment	**Weighting**
Examination – Exam in Quantum Optics & Lasers	50%
Examination – Exam in Electromagnetic Theory	40%
Continuous Assessment in Electromagnetic Theory	10%

PYU33P03 Condensed Matter I

Michaelmas Term – 30 lectures/tutorials – 5 credits (I Shvets)

Part I: Crystal Structure
Part II: Thermal & Electronic Properties

Learning Outcomes
On successful completion of this module, students should be able to:

- Describe crystal structure in terms of translational and rotational symmetry, conventional unit cell, and Miller indices
- Demonstrate the relationship between direct lattice and reciprocal lattice
- Calculate crystal structure parameters from experimental diffraction data
- Describe the main characteristics of the vibrational dispersion curves and the electronic band structure of crystalline metals, semiconductors and insulators
- Apply the free electron and nearly free electron models to the quantitative analysis of the transport properties of real metals
- Provide a quantitative interpretation of the heat capacity of insulators and metals, including temperature dependence

Syllabus

Part I: Crystal Structure
Crystal systems, Bravais lattices, unit cell parameters, translational and rotational symmetry elements, point groups, space groups, Miller indices. The reciprocal lattice. X-ray and neutron scattering. Laue conditions, Bragg's Law. Diffraction patterns and their interpretation. Crystal field explained using the example of 3d electronic wavefunctions. Crystal defects. Points defects. Variation of the crystal field caused by point defects. Jahn-Teller effect. One-dimensional defects: dislocations. Energetics and thermodynamics of defects. Equilibrium density of point defects.

Part II: Thermal & Electronic Properties
Plane waves in free space and in crystals, Bloch functions, Brillouin zones and diffraction in crystals, crystal binding. Atom dynamics in crystals. Electron dynamics in crystals, Free electron model, Nearly free electron model. Real metals, semiconductors and insulators. Electron and hole concepts. Thermal and electric conductivities. Lattice and electronic contributions to heat capacity. Umklapp processes and anharmonic effects.

Assessment	**Weighting**
Examination	90%
Continuous Assessment	10%

PYU33P04 Condensed Matter II

Hilary Term – 30 lectures/tutorials – 5 credits (JMD Coey, D O'Regan)

Part I: Magnetic Properties
Part II: Physics of Semiconductors

Learning Outcomes
On successful completion of this module, students should be able to:
- Describe magnetism in solids in terms of the angular momentum of the electrons, distinguishing between the spin and orbital contributions
- Calculate the ground-state terms of free ions from Hund's rules and their Curie-law susceptibility
- Describe the characteristic physical properties of a ferromagnet, including heat capacity and domain structure
- Describe the basic behaviour of semiconductors in terms of doping and carrier concentrations
- Calculate the dynamic behaviour of semiconductors in terms of drift, diffusion, generation, recombination and the consequences of inhomogeneous doping
- Discuss the importance of magnetism and semiconductors for consumer products and the information revolution

Syllabus

Part I: Magnetic Properties
In these lectures we present the quantum theory and properties of paramagnetic ions, treat ferromagnetic order in the molecular field approximation, and provide an introduction to hysteresis and micromagnetism. Topics include: Units in magnetism, spin and orbital moments of the electron, atomic magnetism of single and multi-electron atoms, spin-orbit coupling, Landé g-factor, Zeeman splitting, vector model of the atom. Paramagnetism – classical Langevin theory, quantum theory for S = 1/2 and general spin (Brillouin theory). Curie law. Ferromagnetism-Weiss molecular field theory. Curie temperature, Curie-Weiss law. Origin of ferromagnetism. Heisenberg Hamiltonian. Positive and negative exchange. Demagnetising field. Ferromagnetic domains; hysteresis and coercivity. Magneto-crystalline anisotropy. Stoner-Wohlfarth model. Permanent magnets. Superexchange, molecular field theory of antiferromagnetism. Ferrites. Applications. Analogies with dielectric properties of solids.

Part II: Physics of Semiconductors
Introduction to semiconductors. Charge carrier densities and Fermi level. Intinsic and extrinsic conductivity, doping with impurities. Carrier transport: drift, mobility, diffusion. Motion in magnetic fields: Hall effect and Cyclotron Resonance. Optical processes, optical absorption. Generation and recombination, minority carrier lifetime, photoconductivity. Non-equilibrium transport of charge carriers, the continuity equation. Inhomogeneous doping. The pn junction diode: depletion layer, built-in potential, electric field, current flow. Uses of diodes.

Assessment	**Weighting**
Examination – Exam in Magnetic Properties	50%
Continuous Assessment in Physics of Semiconductors	10%
Examination – Exam in Physics of Semiconductors	40%

PYU33P05 Atomic & Nuclear Physics

Hilary Term – 30 lectures/tutorials – 5 credits (D. O’Carroll, P Eastham)

Part I: Atomic & Molecular Spectroscopy
Part II: Nuclear Structure

Learning Outcomes
On successful completion of this module, students should be able to:

- Describe the gross and fine structure of single-electron atoms in light of the semi-classical Bohr and quantum mechanical Schrödinger models
- Apply the laws of quantum mechanics to multi-electron atoms, taking into account the effects of angular momentum
- Explain molecular spectra in terms of vibrational, rotational and electronic transitions
- Describe how the atomic nucleus is structured, reacts and decays
- Perform analytical calculations associated with the structure of the nucleus
- Deduce level structures and decay schemes from experimental evidence

Syllabus

Part I: Atomic & Molecular Spectroscopy
One-electron and multi-electron atoms, orbital and spin angular momentum, shell structure, Aufbau principle, electric and magnetic moments, spin-orbit coupling and fine structure, Lamb shift, addition of angular momenta, term symbols, electric dipole and quadrupole and magnetic dipole selection rules, atomic energy levels and spectroscopies in electric and magnetic fields, linewidths, chemical binding in molecules, rotational, vibrational and electronic spectroscopies of molecules, traps, condensates and 'slow light'.

Part II: Nuclear Structure
Strong and electromagnetic forces and the nuclear potential. Conservation laws, including those for parity and symmetry. Nuclear sizes and their measurement. Nuclear electromagnetic moments. Nuclear models, including liquid drop, shell, collective and cluster effects. Gamma decay, internal conversion. Beta decay, the Fermi theory. Nuclear reactions.

Assessment	**Weighting**
Examination	100%

PYU33P06 Dynamical Systems

Michaelmas Term – 30 lectures/tutorials – 5 credits (G Cross, J Pethica)

Part I: Statistical Thermodynamics
Part II: Mechanics of Matter

Learning Outcomes

On successful completion of this module, students should be able to:

- Apply the concepts of inter-atomic potentials and forces to solid media
- Distinguish between elastic and non-elastic solid media
- Describe liquids and gases in terms of fluid flow mechanics
- Outline the basic concepts of equilibrium statistical thermodynamics
- Describe mathematically the behaviour of physical systems governed by Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann statistics
- Determine the partition functions of simple quantum systems

Syllabus

Part I: Statistical Thermodynamics

The purpose of this course is to introduce Statistical Thermodynamics, which provides a microscopic understanding of the macroscopic thermodynamic properties of materials. A simple assumption of equal statistical weights allows the properties of individual quantum particles to be combined together properly to calculate macroscopic thermodynamic quantities, which can be compared with experiment. Topics covered (1) Counting states in classical and quantum systems (2) Fundamental assumption of statistical physics; ensembles (3) Model system of 2-state components (4) Two systems in equilibrium: entropy, temperature and chemical potential (5) Partition functions and their relation to thermodynamic quantities (6) Third Law of Thermodynamics (7) Fermi-Dirac and Bose-Einstein Statistics (8) Quasi-classical statistics: equipartition of energy (9) Application of quantum statistics to photons, gases, and solids.

Part II: Mechanics of Matter

Atomic origins: inter-atomic potentials and forces, virial expansion, deformation. Elasticity: Young's modulus, stress and strain, hydrostatic and shear components. Beyond elasticity: Breakdown of Hooke's law, plasticity, dislocations, work hardening, energy dissipation and friction. Liquids: Fluid flow, boundary layers, atomic and molecular characteristics. Gases. Mechanics in practice at different scales.

Assessment	Weighting
Examination	100%

PYU33P07 Experimental Techniques

Hilary Term – 30 lectures 5 credits (J McCauley, M Hegner)

Part I: Electronics
Part II: Instrumentation

Learning Outcomes
On successful completion of this module, students should be able to:

- Design basic circuits' power supply, communications and computer-interfacing
- Apply bandwidth-narrowing techniques to improve the signal-to-noise ratio in measurements
- Select imaging detectors for a given application, with regard to resolution, sensitivity and wavelength
- Distinguish between the different forms of scanning probe microscope (SPM) and discriminate between real SPM image features and image artefacts
- Describe the principles of optical tweezers (OT) and choose the appropriate light source for OT applications in life-science experiments
- Extend the diagnostic application of cantilever array technology into the wider fields of physics, chemistry and life science

Syllabus

Part I: Electronics
Electronic components. Power supplies. Computers and interfacing. Sensors and transducers. Control systems. Noise in electronic systems.

Part II: Instrumentation
Scanning Probe Microscopes (Scanning Tunneling Microscopy, Scanning Force Microscope, Scanning Nearfield Optical Microscope); Sensors (tunnelling current, force, optical, capacitance, piezoresistance); Motion (piezo electrics, stepper motors, etc.); Environments (UHV, Ambient, liquid, high temperature); Detectors for visible light: position sensitive detectors, photomultipliers, avalanche photodiodes, solid state junction detectors; Software interface (e.g. LabVIEW); Feedback electronics; Multiplexing; Optical tweezers; Cantilever Array devices; Functionalization strategies, description of current research.

Assessment	**Weighting**
Examination	100%

PYU33PP1 Practical in Physics

Michaelmas Term, Hilary Term – 20 credits (W Blau, G Cross, C McGuinness)

Part I: Practical Laboratory – 21 experimental laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 18 lectures/workshops
Part III: School Seminars – 8 seminars

Learning Outcomes
On successful completion of this module, students should be able to:

- Operate advanced apparatus from manual instruction
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment
- Write a précis of a research seminar
- Make a scientific presentation to an audience
- Create a personal CV

Syllabus

Part I: Practical Laboratory – 21 experimental laboratory sessions (of 6 hours duration).

Part II: Communication Skills – 18 lectures/workshops Effective communication of scientific results and ideas as written reports and oral presentations. The structure of a scientific article. The role of graphics and diagrams. Style and vocabulary. Addressing an audience. Use of slides and overheads. Class members will give a short seminar to the entire JS lab group and write an essay on topical issues in physics.

Part III: School Seminars – 8 seminars

Assessment	Weighting
Assessment – Laboratory practical work	90%
Assessment – Careers workshop and seminars	10%

PYU33PP2 Practical in Physics (with Broad Curriculum module)

Michaelmas Term, Hilary Term – 15 credits (W Blau, G Cross, C McGuinness)

Part I: Practical Laboratory – 11 experimental laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 18 lectures/workshops
Part III: School Seminars – 8 seminars

Learning Outcomes
On successful completion of this module, students should be able to:
- Operate advanced apparatus from manual instruction
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment
- Write a précis of a research seminar
- Make a scientific presentation to an audience
- Create a personal CV

Syllabus

Part I: Practical Laboratory – 11 experimental laboratory sessions (of 6 hours duration).

Part II: Communication Skills – 18 lectures/workshops. Effective communication of scientific results and ideas as written reports and oral presentations. The structure of a scientific article. The role of graphics and diagrams. Style and vocabulary. Addressing an audience. Use of slides and overheads. Class members will give a short seminar to the entire JS lab group and write an essay on topical issues in physics.

Part III: School Seminars – 8 seminars

Assessment	**Weighting**
Assessment – Laboratory practical work	90%
Assessment – Careers workshop and seminars	10%

PY3TP1 Practical in Theoretical Physics

Michaelmas Term, Hilary Term – 10 credits (J Donegan, JMD Coey, M. Möbius)

Part I: Practical laboratory – 10 experimental laboratory sessions (of 4 hours duration) and 4 computational laboratory sessions (of 4 hours duration). Problems in computational physics are solved in the computational laboratory.
Part II: Communication Skills – 18 lectures/workshops
Part III: School Seminars – 8 seminars

Learning Outcomes
On successful completion of this module, students should be able to:
- Operate advanced apparatus from instruction manual
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment
- Apply computer simulation methods
- Write a précis of a research seminar
- Make a scientific presentation to an audience
- Create a personal CV

Syllabus

Part I: Practical laboratory – 10 experimental laboratory sessions (of 4 hours duration) and 4 computational laboratory sessions (of 4 hours duration).

Part II: Communication Skills – 18 lectures/workshops Effective communication of scientific results and ideas as written reports and oral presentations. The structure of a scientific article. The role of graphics and diagrams. Style and vocabulary. Addressing an audience. Use of slides and overheads. Class members will give a short seminar to the entire JS lab group and write an essay on topical issues in physics.

Part III: School Seminars – 8 Seminars

Assessment	**Weighting**
Assessment – Laboratory practical work	80%
Assessment – Careers workshop and seminars	20%

PYU44A01 Cosmology, Planetary and Space Science

Michaelmas Term, Hilary Term – 44 lectures/tutorials – 10 credits – (P. Gallagher, A. Vidotto, B. Espey)

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe the observed properties of the solar system
- Estimate the initial mass of the solar system using solar nebula theory
- Explain in detail the main solar system formation theories
- Derive the equations responsible for the stability of planetary atmospheres and magnetospheres
- Explain the physics of the Sun and solar wind
- Explain the main exoplanet detection techniques and the physical information we derive from these observations
- Achieve the learning outcomes of the Cosmology module PYU44A05

Syllabus

Part I: Planetary and Space Science
This course starts with a detailed review of the solar interior and energy transport mechanisms in the radiative and convection zone. The solar atmosphere is then discussed, focusing on the physics of the photosphere, chromosphere, transition region and corona. A detailed derivation of Parker's theories of the solar wind and interplanetary magnetic field is given. Finally, we focus on the interaction of the solar wind with planetary magnetospheres and other objects in the solar system. Formation of our solar system, denizens of our solar system, discovery of extra-solar planets and planetary systems.

Part II: Cosmology
The syllabus for this part of the course is given in the following entry for Cosmology PYU44A05.

Proposed Assessment	**Weighting**
Examination in Planetary and Space Science	40%
Continuous Assessment in Planetary and Space Science	10%
Examination in Cosmology	25%
Continuous Assessment in Cosmology	25%

PYU44A05 Cosmology

Hilary Term – 20 lectures/tutorials – 5 credits (B Espey)

Learning Outcomes

On successful completion of this course, students will be able to:

- Appreciate the background to the topic from basic observational results through to more refined studies of the recent past, including the relative youth of physical cosmology.
- Be able to explain the basic concepts of the subject and the basic assumptions made regarding our non-unique place and time in the Universe.
- Derive the basic equations describing the equation of state of matter, radiation, and dark energy, and their evolution in time and to itemise and critically analyse the evidence in favour of the Big Bang.
- Explain how recent observations of distance and velocity of distant objects have led to conflict with previously-held models, and how these models have had to be altered to accommodate these observations.
- Critically evaluate the current best-fit models and provide evidence for/against open and closed universes and the importance of dark matter and dark energy in the evolution of our Universe.
- Be able to place cosmology in the context of on-going developments both on very large and very small scales and to summarise the results expected in the near future.

Syllabus

Starting with basic cosmological observations and the basic postulates of the Cosmological Principle, this course derives far-reaching results using information from Newtonian principles. The implications of the most recent results concerning Dark Matter and Dark Energy are also discussed, together with possible future observational and research directions. The connection and derivation of similar results from the application of GR will also be discussed. On completion of the course, students will have an understanding of the basic properties of the Universe, how they have been derived from observational and theoretical approaches, and an appreciation for the youth of the field, and recent and future developments e.g. in the fields of dark energy, dark matter, etc.

Assessment	**Weighting**
Examination	50%
Continuous Assessment	50%

PYU44C01 Computer Simulation II

Hilary Term – 24 lectures/tutorials – 5 credits (C Patterson, M Möbius)

Part I: High Performance Computing
Part II: Numerical Methods

Learning Outcomes
On successful completion of this module, students should be able to:

- Be able to formulate and solve physical problems which require linear algebra techniques
- Be familiar with scientific computing libraries such as SciPy and Gnu Scientific Library
- Be familiar with Fourier methods for signal processing.
- Be able to solve partial differential equations numerically using finite difference methods.
- Be able to implement these methods in Python.

Syllabus

Part I:
Introduction to scientific computing libraries (Gnu Scientific Libray, LAPACK, SciPy), Review of vector spaces and linear algebra, Solution of systems of linear equations, Eigenvalue and eigenvector problems, Matrix decompositions (LU, Cholesky, QR, SVD), Python labs to illustrate algorithms using physical examples.

Part II: Numerical Methods
Review of Fourier series and transforms, Correlation and convolution in Fourier space, Aliasing and spectral leakage in FFT, Signal filtering, Windowing, Solving PDE's analytically and numerically using finite difference methods, Numerical stability and accuracy of finite difference methods, Python labs to implement algorithms discussed in the course.

Assessment	**Weighting**
Examination	75%
Continuous Assessment	25%

PY4N07 Advanced Topics for Nanoscience

Hilary Term – 24 lectures/tutorials – 5 credits (C McGuinness, J Coleman, HZ Zhang)
Students select two topics from the three topics offered (each 12 lectures):

Topic 1: Thin Films
Topic 2: Polymers
Topic 3: Diffraction, Imaging, and Spectroscopy of Nanostructures

Learning Outcomes
On successful completion of this module, students should be able to:

Topic 1: Thin Films
- Predict the crystallography of epitaxial systems
- Make simple models of adsorption and epitaxial growth on surfaces
- Distinguish between different practical methods of thin-film growth and connect this knowledge with modern device technology

Topic 2: Polymers
- Describe the structure and properties of polymer chains and of polymers in liquid and solid environments
- Use mathematical and physical models to describe the properties of polymers and to make predictions about their behaviour
- Describe the outcome of simple experiments and use physical models to interpret the data

Topic 3: Diffraction, Imaging, and Spectroscopy of Nanostructures
- Describe kinematical theory of electron diffraction and diffraction patterns
- Discuss the contrast mechanism of conventional and high resolution transmission electron microscopy
- Explain the physical principles of electron energy loss spectroscopy and energy dispersive X-ray spectroscopy for nanoscale analysis.

Syllabus

Topic 1: Thin Films
Basic concepts, surface crystallography, surface spectroscopy, adsorption, growth energetics, epitaxy basics, epitaxy models, general thin film growth, specialist thin film growth, nanostructures

Topic 2: Polymers
We study polymer physics starting with an introduction to polymers, moving on to energetics of polymer-polymer and polymer-solvent interactions and the configurations of polymer chains. We study polymers in bulk i.e. in the liquid and solid phases, focusing on the physical properties of polymers, in particular viscoelasticity and mechanical properties. Finally we look at advanced polymers such as Kevlar and spider silk.

Topic 3: Diffraction, Imaging, and Spectroscopy of Nanostructures
Crystallographic calculation, metric tensors, reciprocal space, components of electron microscopes, diffraction in electron microscopy, selected area electron diffraction, image formation, Energy dispersive X-ray spectroscopy, Electron energy loss spectroscopy, scanning electron microscope, scanning helium-ion microscope. Secondary electron imaging.

Assessment	**Weighting**
Examination	100%

PYU44P01 Quantum Mechanics and High Energy Physics

Michaelmas Term, Hilary Term – 48 lectures/tutorials – 10 credits (P Eastham, C McGuinness)

Learning Outcomes

On successful completion of this module, students should be able to:

- Apply time-dependent perturbation theory to calculate the effects of time-dependent perturbations on systems with discrete and continuous spectra.
- Describe and obtain through calculation the spin dynamics of single particles in time-dependent magnetic fields.
- Describe bosonic and fermionic many-particle systems and calculate their (dynamic) response to external and internal forces/potentials, including linear momentum, orbital angular momentum, spin, total angular momentum, magnetic moment and energy spectrum.
- Apply symmetry arguments to determine the many-body wavefunction, and the corresponding energy spectrum, of simple molecular structures
- Achieve the learning outcomes of the High-Energy Physics module PYU44P02.

Syllabus

Part I: Quantum Mechanics
States and probability amplitudes, matrix-vector form of quantum mechanics, Dirac notation. Schrodinger and Heisenberg pictures. Spin, angular momentum, Stern-Gerlach experiments. Addition of angular momenta. Two level systems, spin-1/2 particle in a static and time-varying electromagnetic field, time evolution of a matrix element. Time-dependent perturbation theory, interaction of an atom with a time-varying electric field. Scattering and many-particle systems, Born approximation, symmetrisation, wave functions for fermions and bosons.

Part II: High Energy Physics
The syllabus for this part of the course is given in the following entry for High-Energy Physics PYU44P02.

Assessment	**Weighting**
Examination in High Energy Physics	50%
Examination in Quantum Mechanics	25%
Continuous Assessment in Quantum Mechanics	25%

PYU44P02 High Energy Physics

Hilary Term – 24 lectures/tutorials – 5 credits (C McGuinness)

Learning Outcomes

On successful completion of this module, students should be able to:

- Define the properties of the underlying fundamental particles of the Standard Model; distinguish between the fundamental forces, strong and electroweak and detail how interactions between particles occur, as well as the fundamental conservation laws that apply
- Outline the experimental methodology by which detection of high-energy particles occurs in particle physics experiments and describe the design of detection apparatus and of current and planned experiments evaluating the differences between them
- Express the relativistic mechanics necessary for the analysis of the outcome of these experiments; be able to use this knowledge to analyse the outcome of simple two body collisions and formulate an appropriate model for the observed collision
- Discuss the current understanding of quark and lepton mixing, such as CKM matrix; demonstrate how this is observed in experiments probing the electroweak interaction; in e-e+ collisions; in neutrino oscillations; and in CP violation leading to matter-antimatter asymmetries
- Sketch or appraise a Feynman diagram for simple particle interactions while distinguishing between the differing interaction vertices and the gauge bosons involved; give a rough estimate of the probability of the process and evaluate what the most likely higher order contributions would be

Syllabus

An introduction to the theory and experimental investigation of fundamental particles and their interactions. Quantum numbers and conservation laws. Exchange interactions and Feynman diagrams, with applications to strong, weak and electromagnetic interactions in the Standard model. Resonant states. Survey of experimental techniques and results on Charm. The quark model. Unitary symmetry schemes for hadron classification. Bottom and Top quark searches, pp physics, W and Z mesons. Neutrinos and electroweak mixing. Neutral K-mesons. CP violation. Results from LEP. LHC, Standard Model and Higgs boson searches.

Assessment	**Weighting**
Examination	100%

PYU44P03 Condensed Matter and Nanoscience

Michaelmas Term, Hilary Term – 48 lectures/tutorials – 10 credits (JMD Coey, P Stamenov, J Coleman)

Part I: Semiconductor Devices
Part II: Metal Physics and Superconductivity
Part III: Nanoscience

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe the characteristic physical properties of a superconductor (zero resistance, Meissner effect, absence of electronic heat capacity, isotope effect)
- Relate the physical properties to underlying theoretical concepts, especially the energy gap, electron pairing and the two characteristic lengths
- Manipulate the Ginzburg-Landau expression for the free energy to reproduce the phase transition
- Describe in detail the physics of bipolar and unipolar homojunction and heterojunction semiconductor devices, as well as how they are fabricated in both discrete and integrated forms
- Evaluate and predict through analytical calculations the performance of such devices, i. e. their input, output and/or their transfer characteristics
- Integrate the elements of module material to yield an appreciation of potential applications of superconductivity and semiconductor physics in a wide range of electronic devices
- Achieve the learning outcomes for the Nanoscience module PYU44P04.

Syllabus

Part I: Semiconductor Devices

Construction techniques for devices. The planar process, diodes and bipolar transistors. Integrated circuit design. MOSFETs, LEDs and compound semiconductor devices, including Gunn devices, Esaki diodes and high-performance heterojunction transistors. The specialised semiconductor laboratory introduces the students to the manufacturing process and testing requirements of commercial integrated digital electronics. The complete PMOS-FET process is demonstrated and practised by the students.

Part II: Metal Physics and Superconductivity

This course provides a basic account of the phenomena and theory of superconductivity, and its applications including high-Tc oxide superconductors. Resistivity of normal metals: impurity scattering, temperature dependence of resistivity due to electron-phonon scattering. Superconductivity: zero resistance, Meissner effect, thermodynamic treatment of the phase transition. Energy gap from specific heat and tunnelling. Type I and II superconductors. Phenomenological Ginzburg-Landau theory. Penetration depth. Cooper pairs. Correlation length. Results of BCS theory Flux quantization, tunnelling, ac and dc Josephson effects.

Part III: Nanoscience

The syllabus for this part of the module is given in the following entry for Nanoscience PYU44P04.

Assessment	**Weighting**
Examination in Semiconductor Devices	25%
Examination in Metal Physics and Superconductivity	25%
Examination in Nanoscience	50%

PYU44P04 Nanoscience

Hilary Term – 24 lectures/tutorials – 5 credits (J Coleman)

Learning Outcomes

On successful completion of this module, students should be able to:

- Demonstrate knowledge of the structure and properties of nanoscale systems, i.e. those with reduced size in one, two and three dimensions
- Use mathematical and physical models to describe the properties of such systems and make predictions about their behaviour
- Describe the outcome of simple experiments involving nanoscale systems and use physical models to interpret the data
- Draw comparisons and find commonalities between various types of nanomaterials and generalize as to how their structure determines their properties

Syllabus

Introduction to nanoscience; what is nanoscience, debunking nanomyths, classical size scaling, intermolecular interactions, DOS and dimensionality, Moore's law – Fabrication and analysis at the nanoscale; thin film fabrication, lithography and etching, colloids, microscopy, spectroscopy – 0D nanostructures; nanoparticles, structure, electronic properties, semiconducting nanoparticles, molecular nanostructures – 1D nanostructures; nanotubes, electronic properties in 1D, transport, applications – 2D nanostructures; quantum wells, graphene – Nanotechnology; nanomachines, the future

Assessment	**Weighting**
Examination	100%

PYU44P05 Electromagnetic Interactions II

Hilary Term – 24 lectures/tutorials – 5 credits (C Patterson, W Blau)

Part I: Electromagnetic Theory
Part II: Optical Communications

Learning Outcomes
On successful completion of this module, students should be able to:
- Demonstrate knowledge of the foundations and meaning of the Maxwell equations, and of their wave-like solutions using elementary differential operators and their vector relations (gradient, divergence, curl)
- Solve problems involving both the electromagnetic fields and their scalar and vector potentials, including the significance of Gauge invariance
- Derive elementary optics relations (such as Snell's law) as a consequence of electromagnetism theory and its boundary conditions
- Discuss the physical principles of lasing, light guiding and detection in communications systems
- Explain the basic structure of the optical components in communications systems
- Solve simple numerical problems based on communications devices

Syllabus

Part I: Electromagnetic Theory
A continuation of the JS electromagnetic theory course, with emphasis on electromagnetic waves. Maxwell's equations and the electromagnetic potentials, EM waves. Plane monochromatic EM waves in unbounded media: (a) vacuum or insulator, (b) ohmic conductor, skin effect. Electromagnetic energy, Poynting's vector. Reflection and refraction of EM waves at a plane boundary. Bounded em waves: waveguides. EM radiation due to an oscillating electric dipole.

Part II: Optical Communications
Waveguiding in planar waveguides and optical fibres, dispersion and loss in fibres. Semiconductor laser/LEDs and detectors. Optical fibre communications systems including digital modulation, noise and fundamental limits.

Assessment	Weighting
Examination	100%

PYU44P06 Modern Optics

Hilary Term – 24 lectures– 5 credits (J Donegan, L Bradley)

Part I: Optical Properties of Materials
Part II: Nonlinear Optics

Learning Outcomes

On successful completion of this module, students should be able to:

- Demonstrate a basic knowledge of the classical theory of light propagation in solid materials, together with a knowledge of the quantum theory of absorption and emission in solids
- Interpret the measured optical spectra of solid materials
- Perform calculations of optical properties of solids
- Perform calculations to determine material characteristic parameters and experimental design for wavelength conversion, pulse measurement by autocorrelation, four-wave-mixing and z-scan techniques
- Select materials for nonlinear optical applications based on an understanding of their material properties, especially their birefringent properties and non-linear refractive index.
- Describe nonlinear processes such as second harmonic generation, electro-optic effects, four-wave-mixing, self-phase modulation and optical phase conjugation.

Syllabus

Part I: Optical Properties of Materials

Electron oscillator model of the propagation of light in insulators and metals, complex refractive index, absorption coefficient and dispersion. Effect of energy bands on optical properties, direct and indirect bandgap semiconductors. Exciton absorption in semiconductors and insulators. Optical properties of defects and dopants in semiconductors and insulators.

Part II: Nonlinear Optics

Basic concepts: second and third order nonlinear processes and susceptibilities. Materials and microscopic origins of nonlinearity.
Applications.

Assessment	**Weighting**
Examination	100%

PYU44P07 Advanced Topics

Hilary Term – 24 lectures/tutorials – 5 credits (I Shvets, C McGuinness, J Coleman, M Ferreira, HZ Zhang)

Students select two topics from the five topics offered (each 12 lectures):

Topic 1: Energy
Topic 2: Thin Films
Topic 3: Polymers
Topic 4: Green's Functions in Physics
Topic 5: Diffraction, Imaging, and Spectroscopy of Nanostructures

Learning Outcomes

On successful completion of this module, students should be able to:

Topic 1: Energy

- Identify the different forms of energy production available and their merits and disadvantages
- Contrast the different forms of renewable energies potentially available on the planet, including the technical limitations to their widespread use
- Contrast the carbon penalty associated with different forms of energy production
- Connect the energy efficiency of fossil fuel electricity plant and internal combustion engines to the fundamentals of thermodynamics

Topic 2: Thin Films

- Predict the crystallography of epitaxial systems
- Make simple models of adsorption and epitaxial growth on surfaces
- Distinguish between different practical methods of thin-film growth and connect this knowledge with modern device technology

Topic 3: Polymers

- Describe the structure and properties of polymer chains and of polymers in liquid and solid environments
- Use mathematical and physical models to describe the properties of polymers and make predictions about their behaviour
- Describe the outcome of simple experiments and use physical models to interpret the data

Topic 4: Green's Functions in Physics

- Solve a variety of different linear differential equations using the technique of Green functions, all applied to physically relevant problems both in the classical and quantum realms
- Compare the Green function technique with the standard methods for solving linear problems and critically assess what the best procedure is to deal with each type of problem
- Implement the Green function technique as an efficient way to solve linear problems in classical and quantum physics that are only treatable by numerical methods
- Explore the versatility of the technique to solve problems that are often too complicated by standard methods
- Apply the Green function method to address problems of current relevance in several subfields of research

Topic 5: Diffraction, Imaging, and Spectroscopy of Nanostructures

- Describe kinematical theory of electron diffraction and diffraction patterns
- Discuss the contrast mechanism of conventional and high resolution transmission electron microscopy
- Explain the physical principles of electron energy loss spectroscopy and energy dispersive X-ray spectroscopy for nanoscale analysis.

Syllabus

Topic 1: Energy
Global consumption of energy. Where the energy is expended and how much of it we need to sustain our life style. Sources of energy. Where can we get the energy and how much. Carbon emission. Can the carbon damage be reversed? Renewable energy sources, challenges and options. The two mainstream energy producing conventional devices: steam turbine and combustion engine. Why they are more important than all other devices. Energy efficiency of these devices considered from the first principles of physics. Can it be increased and by how much? Materials science as the key element in the new energy technologies.

Topic 2: Thin Films
Basic concepts, surface crystallography, surface spectroscopy, adsorption, growth energetics, epitaxy basics, epitaxy models, general thin film growth, specialist thin film growth, nanostructures

Topic 3: Polymers
We study polymer physics starting with an introduction to polymers, moving on to energetics of polymer-polymer and polymer-solvent interactions and the configurations of polymer chains. We study polymers in bulk i.e. in the liquid and solid phases, focusing on the physical properties of polymers, in particular viscoelasticity and mechanical properties. Finally we look at advanced polymers such as Kevlar and spider silk.

Topic 4: Green's Functions in Physics
Part 1: Green's function in Classical Physics
Green's function as a useful tool in Mathematical Physics; Green's-function method in the solution of the: Harmonic oscillator problem; Wave equation; Laplace and Poisson equations; Diffusion equation;
Part 2: Green's functions in Quantum Physics and their applications to Materials Science
Green's-function methods for solving the Schrödinger equation; Green's functions and perturbation theory; Scattering theory (single and multiple scattering); Applications: Numerical tools based on the use of Green's functions; Calculating the electronic conductance of a quantum system; Magnetic properties of metals.

Topic 5: Diffraction, Imaging, and Spectroscopy of Nanostructures
Crystallographic calculation, metric tensors, reciprocal space, components of electron microscopes, diffraction in electron microscopy, selected area electron diffraction, image formation, Energy dispersive X-ray spectroscopy, Electron energy loss spectroscopy, scanning electron microscope, scanning helium-ion microscope. Secondary electron imaging.

Assessment	**Weighting**
Examination	100%

PYU4PP2 Physics Research Project

Michaelmas Term, Hilary Term – 20 credits

This module comprises a 9-week full-time research project in Physics or Astrophysics, conducted in a research laboratory in the School, CRANN or elsewhere. Students also attend School seminars (8 seminars).

Learning Outcomes

On successful completion of this module, students should be able to:

- Carry out an open-ended research project through all of its stages: literature study, data collection and data analysis
- Generate a concise research report
- Summarize in poster format the outcomes of a research project
- Make an oral presentation to an audience of peers

Assessment	**Weighting**
Project	100%

PYU4PP5 Problem Solving in Physics

Michaelmas Term– 5 credits

9 tutorials. Techniques for using knowledge of physics to solve general problems will be developed.

Learning Outcomes

On successful completion of this module, students should be able to:

- Participate in group discussion of problem-solving in physics
- Perform calculations that integrate disparate elements of physics

Assessment	**Weighting**
Examination in problem solving	100%

PY4T01 Condensed Matter Theory

Michaelmas Term – 24 lectures/tutorials – 5 credits (S Sanvito)

Learning Outcomes

On successful completion of this module, students should be able to:

- Demonstrate knowledge of the foundations of solid state Physics in terms of non-interacting electrons
- Give a quantum mechanical description of the chemical bond for homonuclear and heteronuclear molecules
- Describe the determination of simple band structure using the tight-binding method
- Perform analytic calculations to solve elementary condensed-matter-related problems (simple molecule spectrum, band-structure of s-like 1D and 2D materials and of graphene)
- Formulate a model based on the concepts learnt to explain simple condensed matter phenomena (e.g. the Peierls distortion)
- Understand the difference between an interacting and a non-interacting problem and formulate a mean-field theory

Syllabus

Introduction: What Hamiltonian? Born-Oppenheimer Approximation; Tight-binding method for molecules; From molecules to solid; Going from 1D to 2D and 3D; C-graphite and C-nanotubes; Interfaces: charge transfer and screening; A proper calculation: the Coulomb potential back; Density Functional Theory; Kohn-Sham equations; The interacting problem; the Hubbard model for two sites and variable number of electrons; The mean field approximation.

Assessment	**Weighting**
Examination	100%

PY4T03 Quantum Optics and Information

Hilary Term – 24 lectures/tutorials – 5 credits (J Goold)

Learning Outcomes

On successful completion of this module, students should be able to:

- Describe the concept of a photon, and relate this to the mathematical treatment of the quantum-mechanical electromagnetic field
- Use this knowledge to calculate basic physical properties of the quantum-mechanical electromagnetic field
- Describe the theory of the interaction of quantized fields with matter
- Use density matrix formalism of composite systems and generalised measurements
- Derive key concepts in bipartite entanglement theory
- Describe key concepts such as data compression and phase estimation
- Understand decoherence models for a single qubit

Syllabus

Planck distribution, shot noise, photon counting statistics, Possonian, sub-Poissonian and super-Poissonian light, mode expansion of the field and cavities, quantization of the field, stimulated emission and lasing, operators for the electric and magnetic fields. Number states and their field distribution. Origin of vacuum fluctuations. Coherent states and their properties. The Jaynes-Cummings model, vacuum Rabi splitting, Rabi oscillations.

Overview of operational viewpoint of quantum mechanics (Bloch sphere, density matrices, composite systems), The Schmidt Decomposition, Purification, Operator Sum representation, Generalised measurements, Data Compression, Accessible Information, Entanglement measures, generalised entropies, quantum teleportation, quantum phase estimation and decoherence models for a single qubit.

Assessment	**Weighting**
Examination	80%
Assessment	20%

PY4TP2 Research Project

Michaelmas Term, Hilary Term – 10 credits

Learning Outcomes

On successful completion of this module, students should be able to:

- Carry out a research project through all of its stages, including literature study, data generation and data analysis
- Generate a concise research report
- Summarize in poster format the outcomes of a research project

Assessment	**Weighting**
Assessment – Project	100%