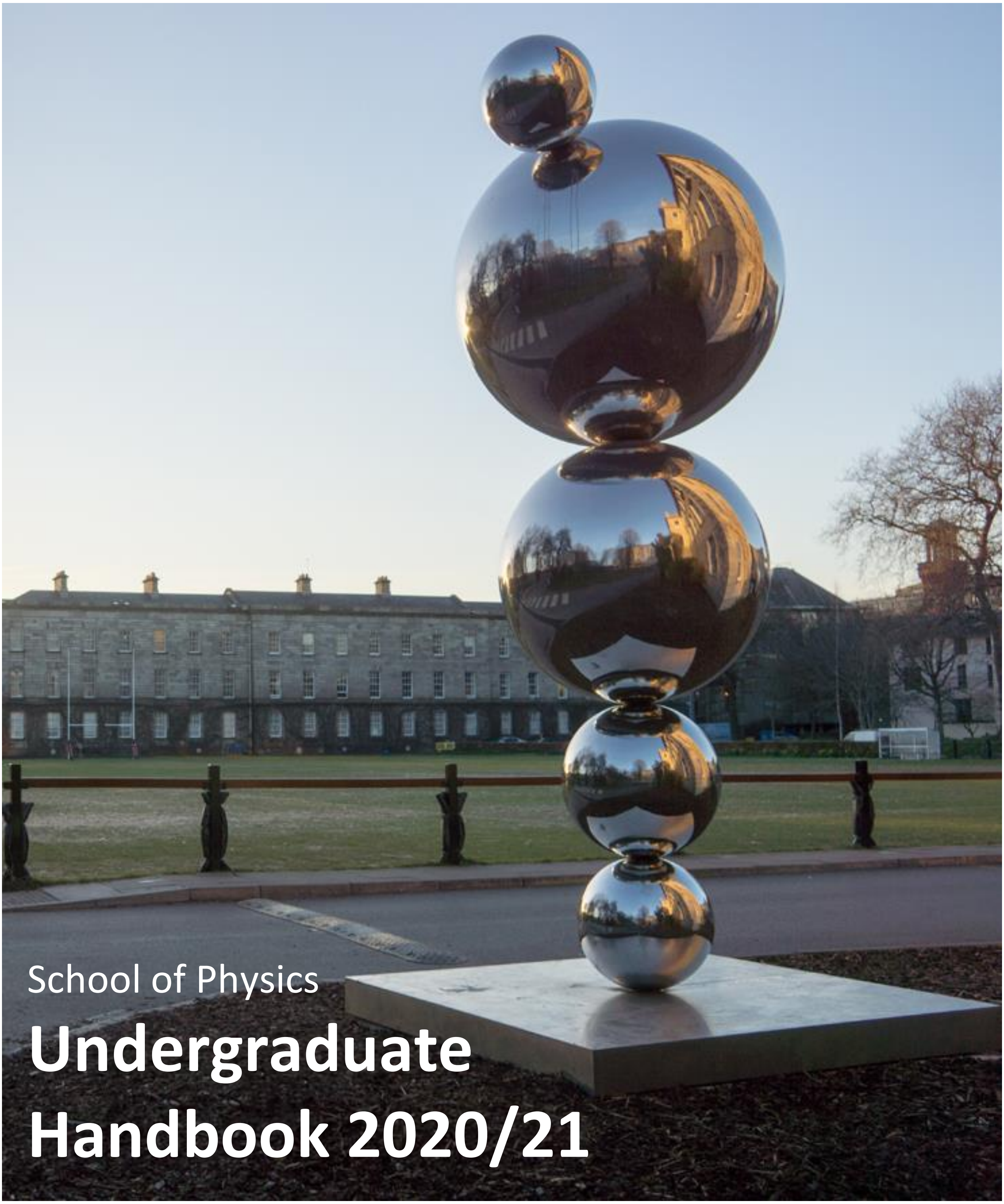
Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin



School of Physics

Undergraduate Handbook 2020/21

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

School of Physics

Faculty of Science, Technology, Engineering and Mathematics

Undergraduate Handbook 2021/22

TR063 ***Physical Sciences*** **– B.A. Moderatorships (Sophister Years)** in

Physics,

Physics and Astrophysics,

Nanoscience

TR035 – B.A. Moderatorship (all years) in

Theoretical Physics

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Important information on COVID-19 restrictions and modes of teaching and learning

In order to offer taught programmes in line with government health and safety advice, teaching and learning in Semester 1 up to reading week for your programme will follow a blended model that combines online and in-person elements to be attended on campus. This blended model will include offering online lectures for larger class groupings, as well as in-person or online classes for smaller groups. The differing modes of teaching and learning for particular modules are determined by your home School. Information on the modes of teaching and learning during the second part of Semester 1 and in Semester 2 will be available closer to the time.

Registered students are expected to be available to attend in-person teaching activities. Any request not to attend in person for exceptional reasons (such as travel restrictions or underlying health conditions) will be considered on a case-by-case basis by the relevant Head of School in consultation with College Health and there is no guarantee that these requests can be facilitated. It will depend on whether the programme learning outcomes and modes of assessment can be met through remote attendance.

For those students not currently in Ireland or planning to undertake travel before the start of term, if they are returning from a country that requires mandatory hotel quarantining or self-quarantining/isolating on arrival in Ireland, they are expected to allow for the period of restricted movement after arrival and prior to commencement of their studies, and therefore should factor this into their travel plans.

We would ask all students to adhere to the safety protocols when on campus for in-person teaching activities or student club and society events, i.e., mask wearing, hand washing, cough etiquette and to maintain social distancing. Please do not congregate outside lecture or tutorial rooms after your classes; we would ask you to exit the building immediately after your event has finished. When term starts on 13 September (or 27 September for first years), students will be permitted on campus for any in-person events that they are involved in. Access to campus will be via a valid student ID card.

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 TR063 reading Physics, Physics and Astrophysics or Nanoscience and all students in TR035 Theoretical Physics (TP). 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 and Senior Fresh students taking Physics in TR060 Biological Sciences, TR061 Chemical Sciences, TR062 Geography and Geosciences, or TR063 Physical Sciences should consult the relevant Handbook for their course, which is available at http://www.tcd.ie/Science.

Junior Sophister students in TR063 Physical Sciences reading Physics, Physics and Astrophysics or Nanoscience should also consult the relevant Sophister Programme Handbook for their course, which is available at https://www.tcd.ie/Science/TR063 .

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 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 28 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.

Contacts in the School of Physics

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School of Physics
Trinity College
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Programme Overview

The School of Physics offers four Moderatorship (honours degree) courses in which Physics is a main component. In addition, students in Junior Fresh (first year) reading TR060 Biological & Biomedical Sciences, TR061 Chemical Sciences or TR062 Geography & Geoscience may choose to take the Physics modules offered for their course of study.

Physics Moderatorship TR063 - Physical Sciences

Physics is a central moderatorship in the School of Physics. Students follow the TR063 Physical Sciences course in their Junior and Senior Fresh years and in both years must take the prescribed Core modules in Physics (20 credits each year) and Mathematics (20 credits and 15 credits). 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, i.e., the physics of solids, 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 both first and second years in Physics (20 credits each year) and Mathematics (20 credits and then 15 credits, respectively) as well as the History, Ethics and Philosophy of Science (5 credits) in the second year. In the Junior and Senior Sophister (third and fourth) years students take a variety of specialist Physics modules. In Junior Sophister year students take a Trinity Elective module (5 credits). In Senior Sophister year students work 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

Physics and Astrophysics Moderatorship TR063 – Physical Sciences

Students follow the TR063 Physical Sciences course in their Junior and Senior Fresh years and must take the prescribed modules in both first and second years in Physics (20 credits each year) and Mathematics (20 credits and then 15 credits, respectively) as well as the History, Ethics and Philosophy of Science (5 credits) in the second year. 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 Senior Sophister year, students work 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

Theoretical Physics Moderatorship TR035

This course is taught jointly by the Schools of Mathematics and Physics. In the first year (Junior Fresh), students take prescribed Physics modules (20 credits) and Mathematics modules (40 credits). In the second year (Senior Fresh), students take prescribed Physics modules (20 credits) and Mathematics modules (20 credits), one 5 credit Trinity Elective in each semester, and choose the remaining 10 credits from among Mathematics and Statistics Open Modules. In the Junior and Senior Sophister (third and fourth) years of the Theoretical Physics course, students may opt to study more Physics or Mathematics modules, depending upon the options available and with certain required module selections. 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

Nanoscience TR063 – Physical Sciences

The Nanoscience degree (formerly known as Nanoscience Physics and Chemistry of Advanced Materials, which was a four-year direct entry course) is taught jointly by the Schools of Physics and Chemistry. Students follow the TR063 Physical Sciences course in their Junior and Senior Fresh years and must take the prescribed modules in both first and second years in Physics (20 credits each year) and Mathematics (20 credits and then 15 credits, respectively) as well as the History, Ethics and Philosophy of Science (5 credits) in the second year. 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 Nanoscience and Advanced Materials. Junior Sophister students take a Nanoscience and Advanced Materials laboratory class including an introduction to experimental techniques for Nanoscience that is carried out in the research laboratories in CRANN, when conditions allow it. In the Senior Sophister year students work on a research project. In many cases, when conditions allow it, 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

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, made up of 30 credits in each Semester. 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, and there is also provision for 'qualified pass' of modules as described in the Calendar Part II Undergraduate Studies Part B1 'General Regulations and Information'. The final degree mark in each Moderatorship is calculated using a weighted combination of the JS and SS year marks, using the formulae described for each degree course in the Calendar Part II Undergraduate Studies Part C6 'Faculty of Science, Technology, Engineering and Mathematics.

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

Scholarships, Prizes and Awards

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.

McGilp Prize – awarded to the student who completes what is judged to be the best Senior Sophister project undertaken in the School of Physics in the year.

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 Trinity College Dublin, **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 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 Dublin'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 intention 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:

1. *(a)* copying another student's work;
2. *(b)* enlisting another person or persons to complete an assignment on the student's behalf;
3. *(c)* procuring, whether with payment or otherwise, the work or ideas of another;
4. *(d)* quoting directly, without acknowledgement, from books, articles or other sources, either in

printed, recorded or electronic format, including websites and social media;

5. *(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:

1. (i) fail to distinguish between their own ideas and those of others;
2. (ii) fail to take proper notes during preliminary research and therefore lose track of the

sources from which the notes were drawn;

3. (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;

4. (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 submitted 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://libguides.tcd.ie/plagiarism.

101 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 them 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.

102 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.

103 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:

1. *(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;

2. *(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;
3. *(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.

104 Provided that the appropriate procedure has been followed and all parties in §101 above are in agreement with the proposed penalty , the Director of T eaching 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.

105 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.

Non-satisfactory attendance and course work

The School of Physics strictly implements Trinity College Dublin'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 Dublin policy on non-satisfactory attendance (excerpt from the College Calendar)

Non-satisfactory attendance

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

25 At the end of the teaching term, students who have not satisfied the school or department requirements, as set out in §§19 and 24 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 www.tcd.ie/academic registry/student- cases.

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

Junior and Senior Fresh Physics

Physical Sciences Students (Junior and Senior Fresh)

There is a separate handbook available for Junior and Senior Fresh Physical Sciences. These are available at: https://www.tcd.ie/Science/TR063/junior-freshman/junior-fresh.php and https://www.tcd.ie/Science/TR063/senior-freshman/

Junior Fresh Theoretical Physics

In the Junior Fresh year, Theoretical Physics students take prescribed Physics modules (20 credits) specified here and Mathematics modules (40 credits) specified by the School of Mathematics.

PYU11T10 Physics for Theoretical Physics – 10 credits
Michaelmas Term – 45 lectures, practical laboratory, online & small group tutorials

PYU11T20 Physics for Theoretical Physics – 10 credits
Hilary Term – 47 lectures, practical laboratory, online & small group tutorials

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

JF Practical Laboratory Classes – Michaelmas Term, Hilary Term

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

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 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 Academic Registry website. Each module, PYU11T10 and PYU11T20, is normally examined in a separate 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 achieve Qualified Pass, according to the rules of the course they are taking, or present for reassessment in the module.

Senior Fresh Theoretical Physics

In the Senior Fresh year, Theoretical Physics students take prescribed Physics modules (20 credits) specified below and Mathematics modules (20 credits) specified by the School of Mathematics, one 5 credit Trinity Elective in each semester, and choose the remaining 10 credits from among Mathematics and Statistics Open Modules.

PYU22T10 Classical Physics for Theoretical Physics – 10 credits
Michaelmas Term – 48 lectures, practical laboratory, project, small group tutorials

PYU22T20 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*.

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 five. 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.

Exams

Information about examinations will be made available on the Academic Registry website. Each module, PYU22T10 and PYU22T20, is examined in a separate examination paper during the relevant end of semester exam session. The overall mark is calculated as follows: PYU22T10 as the weighted average of the exam mark (60%), the laboratory practical mark (25%), the tutorial mark (10%) and the project mark (5%). PYU22T20 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 achieve Qualified Pass or present for reassessment in the module.

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 also choose at least one Trinity Elective (TE) module.

The following modules are mandatory.

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

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

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

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

PYU33P15 Atomic Physics and Statistical Thermodynamics – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33PP3 JS Physics Laboratory – 10 credits
Michaelmas and Hilary Terms – 20 lectures/11 laboratories

PYU33PP4 JS Physics Laboratory – 5 credits
Hilary Term – 7 laboratories

Open Modules: Students must choose from the following modules (maintaining 30 credits per semester):

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

PYU33A17 Astrophysics Techniques – 5 credits
Hilary Term – 30 lectures/tutorials

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

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

At least
One Trinity Elective Module – 5 credits
Either in Michaelmas Term or Hilary Term, or one in each Term.
See https://www.tcd.ie/trinity-electives/

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

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 and PYU33P15 which are assessed entirely by continuous assessment. If the module is examined 100% by examination, four questions will be offered, and students are required to answer two 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 end of this handbook).

If a student does not achieve a pass grade in a module they must either achieve qualified pass (p. 9) or take a supplemental assessment in the failed components of 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 modules (PYU33PP3/4) contributes 15 credits.

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), Physics modules (20 credits), and a further 10 credits from a range of open modules from Mathematics, Phyiscs, and Statistics (options may be restricted dependening on the demand in a given year), totalling 30 credits per semester.

Mandatory modules:

PYU33P03 Condensed Matter I – 5 credits
HilaryTerm – 30 lectures/tutorials

PYU33P15 Atomic Physics and Statistical Thermodynamics – 5 credits
Michaelmas Term – 30 lectures/tutorials

PYU33TP1 Practical in Theoretical Physics – 10 credits
Michaelmas Term, Hilary Term – experimental and computational laboratory classes, seminars and communications workshops

Optional Modules: Students may choose *one* of the following open physics modules:

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

PYU33C01 – Computer Simulation 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.*

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 and PYU33P15 which are assessed entirely by continuous assessment. If the module is examined 100% by examination, four questions will be offered and students are required to answer two 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 end of this handbook).

If a student does not achieve a pass grade in a module they must either achieve qualified pass (p. 9) or take supplemental assessment in the failed components of 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 (PYU33TP1) contributes 10 credits.

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 also choose at least one Trinity Elective (TE) module.

The following modules are mandatory.

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

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

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

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

PYU33A17 Astrophysics Techniques – 5 credits
Hilary Term – 30 lectures/tutorials

PYU33AP3 JS Physics Laboratory – 10 credits
Michaelmas / Hilary Terms – 20 lectures/16 laboratories

PYU33AP4 JS Physics Laboratory – 5 credits
Hilary Term – 7 laboratories

Open Modules: Students must take one specific designated Open module:

PYU33P15 Atomic Physics and Statistical Thermodynamics – 5 credits
Michaelmas Term – 30 lectures/tutorials

They choose from the following other Open modules (maintaining 30 credits per semester):

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

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

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

At least One Trinity Elective Module – 5 credits

Either in Michaelmas Term or Hilary Term, or one in each Term.
See https://www.tcd.ie/trinity-electives/

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

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 and PYU33P15 which are 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 end of this handbook).

If a student does not achieve a pass grade in a module they must either achieve qualified pass (p. 9) or take supplemental assessment in the failed components of 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 modules (PYU33AP3/4) contributes 15 credits.

Junior Sophister Nanoscience

Physics for Junior Sophister Nanoscience students consists of lectures and tutorials delivered in modules, as listed below. There are prescribed modules in Physics (20 credits) as listed below. The balance is made up of prescribed modules in Chemistry (20 credits). The practical advanced materials and nanoscience laboratory module (10 credits) includes laboratory classes and an introduction to experimental techniques for nanoscience carried out in the research laboratories in CRANN (conditions permitting). Students also receive training in communication skills within the practical module. There are further designated Open modules in each semester which must be taken, one in Physics and one in Chemistry.

The following modules are mandatory.

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

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

PYU33NP3 Nanoscience Physics Laboratory – 10 credits
Michaelmas and Hilary Term – 20 Lectures and 12 laboratories

Open Modules: Students must take one specific designated Open module:

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

They then choose from the following other Open modules from the School of Physics or a module from the School of Chemistry:

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

At least One Trinity Elective Module – 5 credits
One Trinity Elective must be in Michaelmas Term, a second may be in Hilary Term – See https://www.tcd.ie/trinity-electives/

Chemistry modules contributing to the Nanoscience Moderatorship are listed in the Sophister Physical Sciences Programme Handbook at https://www.tcd.ie/Science/TR063/junior-sophister/ and on the School of Chemistry website.

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

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 two 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 end of this handbook).

If a student does not achieve a pass grade in a module they must either achieve qualified pass (p. 9) or take supplemental assessment in the failed components of 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 Nanoscience contributes 10 credits. The balance of credits comes from Chemistry modules.

Senior Sophister Physics

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 ordinarily during the first 9 weeks of Michaelmas term, with no lectures during this period. Students select physics Open Modules totalling 20 credits.

The following modules are mandatory.

PYU44P11 Advanced Quantum Mechanics, Nuclear Structure and High Energy Physics – 10 credits
Michaelmas Term, Hilary Term – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 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

Open Modules:

PYU44P13 Magnetism & Superconductivity – 5 credits
Hilary Term – 24 lectures/tutorials

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

PYU44P17 Energy Science– 5 credits
Hilary Term – 24 lectures/tutorials

PYU44N02 Nanoscience, Complex Fluids & Polymers – 10 credits
Michaelmas Term, Hilary Term – 48 lectures/tutorials

PYU44T20 Quantum Optics & Information – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44C01 Computer Simulation II – 5 credits
Hilary Term – 26 lectures/tutorials

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

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

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 achieve qualified pass (p. 9) or take supplemental assessment in failed components of 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 with the exception of PYU44T20 which is assessed entirely by continuous assessment. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer two questions. In cases where a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module. Each component part of 10 credit lecture modules is ordinarily examined in its corresponding end of semester examination period.

If a 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 end of this handbook).

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

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 totalling at least 20 credits. They take 20 mandatory credits of taught modules in Physics. They also take a 10 credit research project in either Physics or Mathematics. The balance is from taught modules in Mathematics, Physics, and/or a single Trinity Elective module.

Mandatory Taught Modules (20 credits):

PYU44P12 Nuclear Structure and High Energy Physics – 5 credits
Hilary Term – 24 lectures/tutorials

PYU44T10 Condensed Matter Theory – 5 credits
Michaelmas Term – 24 lectures/tutorials

PYU44T20 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):

PYU44TP2 Research Project – 10 credits
OR MA4492 Project – 10 credits
Michaelmas Term, Hilary Term – Research project, meetings with supervisor by arrangement.

Optional Taught Modules (PYU44A01 and PYU44A05 cannot both be selected):

PYU44P13 Magnetism & Superconductivity – 5 credits
Hilary Term – 24 lectures/tutorials

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

PYU44P17 Energy Science– 5 credits
Hilary Term – 24 lectures/tutorials

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

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*.

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 achieve qualified pass (p. 9) or take supplemental assessment in the failed components of that module.

Each 5-credit lecture module will be examined separately in the relevant end of semester examination period, period with the exception of PYU44T20 which is assessed entirely by continuous assessment. If a 5-credit module is examined 100% by examination, four questions will be offered and students are required to answer two questions. In cases where 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 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 end of this handbook).

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

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 ordinarily during the first 9 weeks of Michaelmas term, with no lectures during this period. Students select physics Open Modules totalling 10 credits.

The following modules are mandatory.

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

PYU44P11 Advanced Quantum Mechanics, Nuclear Structure and High Energy Physics – 10 credits
Michaelmas Term, Hilary Term – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 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

Open Modules:

PYU44P13 Magnetism & Superconductivity – 5 credits
Hilary Term – 24 lectures/tutorials

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

PYU44P17 Energy Science– 5 credits
Hilary Term – 24 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*.

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 achieve qualified pass (p. 9) or take supplemental assessment in the failed components of 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. 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 a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module. Each component part of 10 credit lecture modules is ordinarily examined in its corresponding end of semester examination period.

If a 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 end of this handbook).

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

Senior Sophister Nanoscience

Physics for Senior Sophister Nanoscience 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 (conditions permitting). Students select physics and/or chemistry Open Modules totalling 15 credits.

The following modules are mandatory.

PYU44N02 Nanoscience, Complex Fluids & Polymers – 10 credits
Michaelmas Term, Hilary Term – 48 lectures/tutorials

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

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

Open Modules (only physics modules are shown):

PYU44P13 Magnetism & Superconductivity – 5 credits
Hilary Term – 24 lectures/tutorials

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

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

PYU44P17 Energy Science– 5 credits
Hilary Term – 24 lectures/tutorials

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

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 achieve qualified pass (p. 9) or take supplemental assessment in the failed components of 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. 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 a 5-credit module is taught in two parts, students must answer one question relating to each of the two parts of the module. Each component part of 10 credit lecture modules is ordinarily examined in its corresponding end of semester examination period.

If a 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 end of this handbook).

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

The balance of credits comes from Chemistry modules.

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 (https://student-learning.tcd.ie/learning-resources/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: www.tcd.ie/physics

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 –13.00

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/about/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 at www.tcd.ie/Physics/about/safety.

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.

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.

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	Dr. Victor Usov	3530 (01-896 3530)
Radiological Protection	Dr. Maria Stamenova	8454 (01-896 8454)
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

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

TCD.Careers.Service

@TCDCareers

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 sci-fi. 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

PYU11T10 Physics for Theoretical Physics

Semester 1 – MT – lectures, practical laboratory, online & small group tutorials – 10 credits
(G. Cross, A. Droghetti, 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%

PYU11T20 Physics for Theoretical Physics

Semester 2 HT – lectures, practical laboratory, online & small group tutorials – 10 credits
(A. Lunghi, P. Eastham, TBC)

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%

PYU22T10 Physics for Theoretical Physics

Semester 1 MT – 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
Materials – 12 lectures
Oscillations – 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
- Describe Maxwell's equations in the integral form and apply them to solve problems with simple electric and magnetic geometries.
- Relate the electromagnetic laws to the working principles of basic circuit elements and apply circuit laws and theorems to solve dc/ac circuits.

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; Resistance, capacitance, mutual inductance and self-inductance; Nodal and mesh analysis, Thevenin theorem, R-C and R-L circuits, AC circuits, phasor diagrams, reactance, resonance, and complex representation of reactance. Power analysis.

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%

PYU22T20 Physics for Theoretical Physics

Hilary Term – lectures, practical laboratory, small group tutorials – 10 credits (S Hutzler, M Stamenova, TBC, 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

Models of the atom. Rutherford scattering. Scattering cross-section. Nuclear radius and density. Nuclear force. Nuclear binding. Nuclear masses. Mass defect. The Segrè chart. Nuclear models: the liquid drop model and the shell model. Mass dependence of binding energy per nucleon. Atomic mass parabola for isobars. Beta decay. Electron, positron emission. Electron capture. Alpha decay. Heavy element decay chains. Barrier penetration mechanism. Gamma decay. Radioactive decay law. Analysis of parent-daughter activity relationships. Specific activity. Radiometric dating. Harmful effects of radiation and dosimetry. Nuclear reactions. Nuclear fission. 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 and interactions. Positron discovery and the Dirac theory. Antiparticles. Neutrinos. Interaction mediating particles. Yukawa potential. Particle accelerators. Leptons and hadrons. Fermions and bosons. Particle reactions and conservation laws. Quarks and gluons. The Standard Model.

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%

PYU33A03 Stellar and Galactic Structure

Michaelmas Term – 30 lectures/tutorials – 5 credits (S. Jeffery, B. Espey)

Overview

This module provides an in-depth view on the physics that govern how stars and galaxies evolve. The universe became a fundamentally different place when the first stars formed about 150 million years after the Big Bang. From this point on, new chemical elements were synthesized, photons were produced on massive scales by nuclear reactions in stars, and galaxies were assembled through collapse and mergers. We will cover the observational quantities that we can measure such as temperature, luminosity, and metallicity. We will derive the fundamental theory that explain the observations of stars and galaxies throughout the history of the universe.

Part I: Stellar Astrophysics
Part II: Galactic and Extragalactic Astrophysics

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

Properties of radiation and their applications to stellar interiors: specific intensity, flux, luminosity, and effective temperature; Stellar opacities: sources, optical depth, Rosseland mean opacity; Stellar structure: hydrostatic equilibrium, mass conservation, equation of state, energy sources and transport; Stellar models: equations of stellar structure and boundary conditions; Stellar evolution: initial mass function, main sequence, hydrogen burning, advanced stages, low mass stellar evolution, high mass stellar evolution; Remnants and Compact Objects: white dwarfs, neutron stars, black holes; Physics of stars in binary systems.

Part II: Galactic and Extragalactic Astrophysics

The basic constituents of galaxies; the properties and dynamics of the Milky Way; the Local Group of galaxies; galaxy types, modern classification, and fundamental properties ; stellar distribution and dynamics in spiral and elliptical galaxies; methods for measuring distances, masses, and luminosities of galaxies, and their limitations; the Virial Theorem applied to galaxies; star-formation histories and chemical evolution of galaxies; dark matter on galactic and extragalactic scales; galaxy clusters; active galaxies and supermassive black holes

Assessment	**Weighting**
Examination in Stellar & Galactic Structure	80%
Continuous Assessment in Stellar Astrophysics	10%
Continuous Assessment in Galactic and Extragalactic Astrophysics	10%

PYU33A17 Astrophysics Techniques

Hilary Term – 5 credits (B Espey)

Overview

Imaging and spectroscopy across the full EM spectrum is the primary means for determining the properties and characteristics of astronomical objects. This module provides an introduction to instrumentation for a range of astrophysical investigations, focussing on the optical and radio portions of the spectrum. The basics of radiative transfer and its underlying micro and macro physics are introduced and the application to a number of specific practical problems is also covered. Examples of specific investigations using real-world examples and data are used.

Part I: Astrophysical Instrumentation
Part II: Astrophysical Spectroscopy

Learning Outcomes

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

· Give an overview of different types of telescopes and detection techniques appropriate for specific astronomical investigations, including their advantages and limitations

· Describe the processes that limit the angular resolution and sensitivity of telescopes both in terms of theoretical and also in atmospheric-limited cases and the techniques used to reduce their influence

· Be able to distinguish between thermodynamic equilibrium (TE), local thermodynamic equilibrium (LTE), & non-LTE, and how these apply in the case of stellar interiors and more generally

· Apply statistical mechanics knowledge to the solution of practical astrophysical problems, including the use of radiative transfer

· Be able to interpret the multi-dimensional stellar classification system with reference to the Saha and Boltzmann equations

Syllabus

Part I: Astrophysical Instrumentation Telescopes and optical instrumentation. Observational limitations – telescope aberrations and 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.

Part II: Astrophysical Spectroscopy Atomic populations and transitions: micro and macro physics, classical and quantum physics. Detailed balance and Einstein relations. Line Profiles. Radiation units. Radiation transfer. Plane-parallel models. Limb darkening. Saha equation. Stellar spectra.

Assessment	**Weighting**
Examination in Astrophysical Spectroscopy and Astrophysical Instrumentation	80%
Continuous Assessment in Astrophysical Spectroscopy and Astrophysical Instrumentation	20%

PYU33AP3 Practical in Physics and Astrophysics

Michaelmas Term and Hilary Term – 10 credits (B Espey, E Carley, W Blau)

Part I: Practical Laboratory – 16 experimental laboratory sessions (of 4 hours duration).
Part II: Communication Skills – 20 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 – 16 experimental laboratory sessions (of 4 hours duration). An introduction to critical thinking in analysis of physical data. Advanced experiments ranging across multiple techniques requiring observations, physical measurements, data acquisition, data analysis, interpretation of physical phenomena and of quantitative results, verification of results, quantification of uncertainties, all of which are to be documented in laboratory notebooks. All experiments performed must be fully analysed, selected experiments will require an analytical report with appropriate experimental and theoretical background, analysis, conclusions, citations and bibliography.

Part II: Communication Skills – 20 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. Introduction to risks, hazards and risk assessments.

Part III: School Seminars – 8 seminars – A broader introduction to cutting edge physics research will occur through attendance at School of Physics seminars.

Assessment	**Weighting**
Continuous Assessment – Laboratory Practical Work	80%
Continuous Assessment – Careers Workshop and Communicatiosn Skills	20%

PYU33AP4 Practical in Physics and Astrophysics – Computational Laboratory (5 credits)

Hilary Term – 7 computational laboratories of 6 hours duration – 5 credits (K Maguire, N Gibson)

Learning Outcomes

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

- Develop computational skills
- Employ computer-based data analysis of multi-dimensional datasets
- Prepare an extended analytical report on an experiment
- Use IDL software in computational astrophysics problems

Syllabus

This module introduces computational Astrophysics to students who have had no programming experience with the Interactive Data Language (IDL). The student will develop computational skills that can be further applied to theoretical, numerical and observational Astrophysical studies. Given that IDL is a software largely used for data analysis, skills learned in this module are transferrable to other areas of studies, such as analytics of big data, data processing and imaging. The module will further equip students to carry out their final year research project in Year 4 of the degree.

This module consists of 7 sessions of 6 hours. The first two sessions are dedicated to introducing IDL through a series of worksheets that students complete at their own pace (discussion among students is highly encouraged). The following sessions are reserved for two numerical experiments. At the end of the module, the student will have learned: the basic IDL commands; how to create, modify and operate with multi-dimensional arrays; create 1D, 2D and 3D plots, including line plots, error plots, scatter plots, images, contours and surfaces; perform linear fitting, log/log, semi-log, and power law analysis; create and use own procedures and functions, as well as those available from widely used public Astrophysical libraries; read and save data in several formats (ascii, fits, csv, etc); how to control the flow of the program execution; work with big data; data interpolation and resampling; and a number of good practices in coding.

Students will cement their learning by conducting experiments that are designed to continue the development of computational skills and personal initiative and will be assessed based on 2 submitted reports (one at the middle and one at the end of the module). Astrophysics applications of the experiments include creating HR diagrams, computing the habitable zones around low-mass stars, working with catalogues of exoplanets, practical analysis of Kepler's 3rd law, working with big datasets from stellar evolution models, analyse and interpret stellar spectra.

Assessment	**Weighting**
Continuous Assessment	100%

PYU33C01 – Computer Simulation I

Michaelmas Term – 30 lectures/tutorials – 5 credits (S Hutzler, F Pietracaprina)

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%

PYU33NP3 Practical in Nanoscience

Michaelmas Term and Hilary Term – 10 credits (L Jones, W Blau)

Part I: Practical Laboratory – 11 experimental laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 20 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
· Be familiar with nanoscience and advanced materials characterisation techniques
· 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). An introduction to critical thinking in analysis of physical data. Advanced experiments ranging across multiple techniques requiring observations, physical measurements, data acquisition, data analysis, interpretation of physical phenomena and of quantitative results, verification of results, quantification of uncertainties, all of which are to be documented in laboratory notebooks. All experiments performed must be fully analysed, selected experiments will require an analytical report with appropriate experimental and theoretical background, analysis, conclusions, citations and bibliography. An extended practical introduction to nanoscience and advanced materials characterisation techniques will be part of the nanoscience practical laboratory.

Part II: Communication Skills – 20 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. Introduction to risks, hazards and risk assessments.

Part III: School Seminars – 8 seminars – A broader introduction to cutting edge physics, chemistry and ananoscience related research will occur through attendance at selected School of Physics and School of Chemistry seminars.

Assessment	**Weighting**
Continuous Assessment – Laboratory Practical Work	80%
Continuous Assessment – Careers Workshop and	20%

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	85%
Assessments	15%

PYU33P02 Electromagnetic Interactions I

Michaelmas 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 in Quantum Optics and Lasers	50%
Continuous Assessment in Electromagnetic Theory	50%

PYU33P03 Condensed Matter I

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

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 X-ray 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
- Develop understanding of the effective mass of the current carriers and its relation to the energy-momentum dispersion curves.
- Develop a qualitative understanding of the electron-electron scattering processes.
- Become familiar with the different types of magnetic order: ferromagnetic and antiferromagnetic order, develop understanding of the factors defining the type of the magnetic order.
- Develop understanding of behaviour of ferromagnetic materials placed in a magnetic field.

Syllabus

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 condition, Bragg's Law and their equivalence. Ewald construction for X-ray diffraction. X-ray diffraction patterns and their interpretation. Geometrical structure factor and atomic form factor.
Crystal defects. Points defects. One-dimensional defects: dislocations. Energetics and thermodynamics of defects. Equilibrium density of point defects.
Stress and strain in matrix form in the case of isotropic materials, Poisson ratio, stress and strain in non-isotropic materials. Stiffness and compliance matrixes for materials for different crystal systems.

Acoustic waves in isotropic media, longitudinal and transversal modes. Counting vibrational states in the case of standing waves in periodic systems, density of states in k-space, Debye frequency. Counting vibrational states in the case of running waves, Born Von Karman boundary condition. Deriving vibrational states in the case of a 1D crystal model with identical atoms, significance of the first Brillouin zone. Derivation of the dispersion curve in the case of a 1D crystal model with two different sets of atoms, derivation of the acoustic and optics modes. Phonon dispersion curves in real 3D crystals. Phonon as a quasiparticle, its similarity with and difference from a real particle. Derivation of heat capacity dependencies arising from phonons.
Electrons as a gas, Fermi function, definition of the Fermi energy. Electronic heat capacity. Derivation of the energy bands in the 1D case of a nearly free electron model. Presentation of energy bands in reduced-, extended- and repeated zone schemes. Bloch functions and theorem.
Definition of electrons and holes from the point of view of the Fermi surface. Electrical conductivity, dynamics of electrons in crystalline solids, effective mass for electrons and holes and its definition from the dispersion curves, electron-electron scattering, mean free path, electron- and hole dynamics in the presence of magnetic field. Magnetic order, magnetic moment, H-field and B-field in the case of ferromagnetic materials, demagnetising field. Magnetism of electrons, spin-orbit coupling.
Electron-spin resonance in paramagnetic materials and ferromagnetic resonance.

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

PYU33P04 Condensed Matter II

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

Part I: Physics of Semiconductors
Part II: Semiconductor Devices

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

- 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
- Describe in detail the physics of bipolar and unipolar homojunction and heterojunction semiconductor devices.
- Evaluate and predict through analytical calculations the performance of such devices, i. e. their input, output and/or their transfer characteristics
- Discuss the semiconductors for consumer products and the information revolution

Syllabus

Part I: Physics of Semiconductors
Introduction to semiconductors. Charge carrier densities and Fermi level. Intrinsic 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.

Part II: Semiconductor Devices

Construction techniques for devices. The planar process. The pn junction diode: depletion layer, built-in potential, electric field, current flow. Uses of diodes. Bipolar transistors. MOSFETs, LEDs and compound semiconductor devices, including Gunn devices, Esaki diodes and high-performance heterojunction transistors

Assessment	**Weighting**
Examination in Semiconductor Devices	50%
Continuous Assessment in Physics of Semiconductors	50%

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%

PYU33P15 Atomic Physics & Statistical Thermodynamics

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

Overview

From individual multi-electron atoms, electron interactions within the atom, and the resultant electronic structure of the atom, to ensembles of particles and their collective behaviour, this module provides a foundational overview of complex quantum behaviours and interactions.

Part I: Statistical Thermodynamics
Part II: Atomic Physics

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
- 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: Atomic and 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'.

Assessment	**Weighting**
Continuous Assessment in Statistical Thermodynamics	50%
Continuous Assessment in Atomic & Molecular Spectroscopy	50%

PYU33PP3 Practical in Physics

Michaelmas Term and Hilary Term – 10 credits (W. Blau, G. Cross, C. McGuinness, M. Möbius)

Part I: Practical Laboratory – 11 experimental laboratory sessions (of 6 hours duration).
Part II: Communication Skills – 20 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). An introduction to critical thinking in analysis of physical data. Advanced experiments ranging across multiple techniques requiring observations, physical measurements, data acquisition, data analysis, interpretation of physical phenomena and of quantitative results, verification of results, quantification of uncertainties, all of which are to be documented in laboratory notebooks. All experiments performed must be fully analysed, selected experiments will require an analytical report with appropriate experimental and theoretical background, analysis, conclusions, citations and bibliography.

Part II: Communication Skills – 20 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. Introduction to risks, hazards and risk assessments.

Part III: School Seminars – 8 seminars – A broader introduction to cutting edge physics research will occur through attendance at School of Physics seminars.

Assessment	**Weighting**
Continuous Assessment – Laboratory Practical Work	80%
Continuous Assessment – Careers Workshop and	20%

PYU33PP4 Practical in Physics

Hilary Term – 5 credits (G. Cross, C. McGuinness, M. Möbius)

Practical Laboratory – 8 experimental laboratory sessions (of 6 hours duration).

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
- Perform a range of complex non-linear data fitting
- Use physics simulation software or design data acquisition software

Syllabus

Practical Laboratory – 8 experimental laboratory sessions (of 6 hours duration). A continuation of advanced experiments ranging across multiple techniques requiring observations, physical measurements, data acquisition, data analysis, interpretation of physical phenomena and of quantitative results, verification of results, quantification of uncertainties, all of which are to be documented in laboratory notebooks. All experiments performed must be fully analysed, selected experiments will require an analytical report with appropriate experimental and theoretical background, analysis, conclusions, citations and bibliography.

In addition, an introduction to non-linear curve fitting and multivariate analysis of complex data and/or large data sets. Further choice in the introductions to simulation software applied to physics problems or of developing data acquisition software and strategies for interfacing and control of experiments.

Assessment	**Weighting**
Continuous Assessment – Laboratory Practical Work	100%

PYU33TP1 Practical in Theoretical Physics

Michaelmas Term, Hilary Term – 10 credits (W Blau, J Donegan, JMD Coey, P Eastham, M Mitchison, TBC)

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 – (B. Espey, P. Gallagher, N. Gibson)

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 & Cosmology	50%
Continuous Assessment in Planetary and Space Science	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%

PYU44N02 Nanoscience, Complex Fluids & Polymers

Michaelmas Term, Hilary Term – 48 lectures/tutorials – 5 credits (J Coleman, M. Möbius)

Overview

This module gives a comprehensive introduction to Nanoscience and the foundations of Polymer physics and Complex Fluids in general.

Part I: Nanoscience
Part II: Complex Fluids
Part III: Polymers

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
- 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
- Demonstrate basic knowledge of fluid dynamics and ability to predict the flow in standard geometries for both Newtonian and non-Newtonian fluids.
- Be able to interpret rheological data for various colloidal suspensions and relate it to physical models that describe the flow behaviour of complex fluids
- Be able to describe and predict the various interparticle forces in colloidal suspensions, the mesoscopic structure these particles can form, and how both the forces and structure relate to the flow properties of these suspensions.

Syllabus

Part I: Nanoscience

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.

Part II: Soft Matter

Introduction: What are complex fluids? Review of hydrodynamics and stress tensor. Origin of viscosity, Stokes drag, diffusion and Stokes-Einstein relation. Colloidal suspensions: Relevant forces between colloidal particles and stability. Rheology of complex fluids: Yield stress, shear thinning, shear thickening. Basic rheology models.

Part III: Polymers

Introduction to polymeric materials- molecular structure and architecture; Interactions between polymers and their surroundings -Energy and entropy; Polymer Chains- conformations of ideal and real chains, chain size; Dynamics- Rouse and Zimm models, reptation, viscosity; Polymers in solid state – Crystallinity, the glass transition, classes of solid polymer; Physical properties of polymers- mechanics, viscoelasticity, stress relaxation/creep, temperature dependence; High performance polymers- rigid rod polymers, spider silk, nanotubes.

Assessment	**Weighting**
Examination in Nanoscience & Complex fluids	50%
Continuous Assessment in Nanoscience	25%
Examination in Polymers	25%

PYU44NP2 Nanoscience Research Project

Hilary Term – 20 credits

This module comprises a 9-week full-time research project conducted in either the School of Chemistry or Physics, CRANN or an internationally recognised research laboratory that specialises in aspects of nanoscience, advanced materials or semiconductor processing.

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%

PYU44NP5 Problem Solving in Nanoscience

Michaelmas Term– 5 credits

This module develops general problem-solving and scientific comprehension in nanoscience, advanced materials or semiconductor processing. Students attend 9 tutorials and a selection of seminars in both the Schools of Chemistry and Physics which are related to nanoscience, materials chemistry, materials physics or related areas.

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 comprehension and problem solving	100%

PYU44P11 Advanced Quantum Mechanics, Nuclear Structure and High Energy Physics

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

Overview

The quantum mechanics part of this module exposes the fundamental principles of quantum mechanics, including Hilbert space, measurement, and time evolution. It looks at applications of these principles in time-dependent and scattering problems, the role of symmetry and angular momentum, and explores how many-particle systems can be treated. The nuclear physics part includes the strong nuclear force, nuclear structure and models, and decays and reactions. The high energy physics part introduces high energy physics theory and experiment, fundamental particles, the fundamental forces, and the Standard Model.

Part I: Advanced Quantum Mechanics
Part II: Nuclear Structure
Part III: High Energy Physics

Learning Outcomes

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

- Apply the fundamental principles of quantum mechanics to solve problems relating to the dynamics and observation of quantum systems.
- Use time-dependent perturbation theory to analyze dynamics and scattering problems, in systems with discrete and continuous spectra.
- Discuss and apply the properties of angular momentum, and its relationship to rotational symmetry.
- Describe and obtain through calculation the spin dynamics of single particles in time-dependent electromagnetic fields
- Construct wavefunctions for many-body systems of bosons and fermions, and analyze the physical consequences of particle identity and exchange.
- Describe the role of symmetry in quantum mechanics. Use symmetry arguments to determine wavefunctions and energy spectra, and analyze transition probabilities.
- Achieve the learning outcomes of the Nuclear Structure and High Energy Physics module PYU44P12.

Syllabus

Part I: Advanced Quantum Mechanics

State vectors, operators, and measurements. Relation between state vector and wavefunction formalisms. Time evolution in the Schrodinger and Heisenberg picture. Time-dependent perturbation theory and Fermi's golden rule. Scattering theory and the Born approximation. Angular momentum, rotational symmetry. Spin. Dynamics of spin in static and time-varying fields. Wavefunctions for many particles, exchange symmetry, bosons and fermions. Addition of angular momentum. Role of symmetry.

Part II: Nuclear Structure

The syllabus for this part of the course is given in the following entry for Nuclear Structure and High-Energy Physics PYU44P12.

Part III: High Energy Physics

The syllabus for this part of the course is given in the following entry for Nuclear Structure and High-Energy Physics PYU44P12.

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

PYU44P12 Nuclear Sructure and High Energy Physics

Hilary Term – 24 lectures/tutorials – 5 credits (O. Hess, C McGuinness)

Overview

This module describes nuclear physics, nuclear structure and models, the strong nuclear force and nuclear decays and reactions. It introduces high energy physics theory and experiment, fundamental particles, the fundamental forces, and the Standard Model.

Part I: Nuclear Structure
Part II: High Energy Physics

Learning Outcomes

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

- 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
- Define the properties of fundamental particles of the Standard Model; the fundamental forces, strong and electroweak, their interactions and the applicable fundamental conservation laws.
- Express the relativistic mechanics for analysis of experimental high energy physics interactions; use this knowledge to analyse simple two body collisions and formulate an appropriate model for the observed collision.
- Discuss quark and lepton mixing, e.g. CKM matrix; and how this is observed in experiments; in e-e+ collisions; in neutrino oscillations; and in CP violation leading to matter-antimatter asymmetries.
- Sketch or appraise a Feynman diagram distinguishing between the differing interaction vertices and the gauge bosons involved; giving estimates of the probability of the process and of the most likely higher order contributions.

Syllabus

Part I: 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.

Part II: High Energy Physics

An introduction to the theory of fundamental particles and their interactions. Quantum numbers, conservation laws, exchange interactions and Feynman diagrams, applied to strong, weak and electromagnetic Standard model interactions. The quark model and resonant states including charmonium and bottomium. Quantum electrodynamics (QED) and quantum chromodynamics (QCD). Electron-positron and p-p physics at LEP and LHC. W and Z mesons, neutrinos and electroweak mixing. Quark mixing. Standard Model and Higgs boson. Beyond the Standard model.

Assessment	**Weighting**
Examination in Nuclear Structure and High Energy Physics	100%

PYU44P13 Magnetism & Superconductivity

Hilary Term – 24 lectures/tutorials – 5 credits (JMD Coey)

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 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.
- Integrate the elements of module material to yield an appreciation of potential applications of superconductivity physics in a range of electronic devices.

Syllabus

Part 1: Magnetism and 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: 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.

Assessment	**Weighting**
Examination in Magnetism and Superconductivity	100%

PYU44P05 Electromagnetic Interactions II
Hilary Term – 24 lectures/tutorials – 5 credits (C Patterson, J. Donegan)

Part I: Electromagnetic Theory
Part II: Optical Properties of Materials

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
- 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

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

Assessment	**Weighting**
Examination	100%

PYU44P06 Modern Optics

Hilary Term – 24 lectures– 5 credits (L. Bradley, W. Blau)

Part I: Nonlinear Optics
Part II: Optical Communications

Learning Outcomes

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

- 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.
- 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 1: Nonlinear Optics

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

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%

PYU44P17 Energy Science

Hilary Term – 24 lectures/tutorials – 5 credits (I Shvets)

Overview

This module gives a comprehensive introduction to science underpinning energy technologies with the emphasis on fundamental physics and materials science defining the concepts of modern energy generation and their technical limitations. The module will discuss current “bread and butter” technologies based on steam turbines providing the bulk of world-wide electricity generation at present. The module will include analysis of nuclear fission reactors that also provide a sizeable fraction of the world’s electricity. It will deal with renewable technologies such as solar photovoltaics whose share in the total energy production is set to increase with the drive to move away from the fossil fuels. Finally, we shall discuss the fundamental physics of nuclear fusion that may open an unlimited supply of fossil-free energy in the future and the challenges to overcome for this.

Learning Outcomes

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

- Identify the different forms of energy production available and their merits and disadvantages
- Understand the fundamental similarities between the mainstream forms of electricity generation based on converting heat into work where the heat source is either gas or oil or coal or nuclear fission.
- Understand the fundamental limitations of the current main stream energy generation based on steam turbines resulting from the first principles of thermodynamics
- Explain the fundamental physics underpinning the architecture of the nuclear fission reactor.
- Explain the fundamentals of energy production by solar photovoltaics cells and the fundamental limitations of this technology.
- Contrast 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
- Explain the fundamental challenges that need to be overcome in the quest towards nuclear fusion.

Syllabus

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. Brief overview of the fundamentals of thermodynamics. Maxwell relations, entropy of the ideal gas, Carnot theorem. Steam phase diagram presented in axes of different variables.

The two mainstream energy producing conventional devices: steam turbine and combustion engine. Why they are still so important. Energy efficiency of the steam turbine considered from the first principles of physics and its fundamental limitations. Mollier Chart. Rankine cycle and the cycle with superheating. Work ratio and its significance for the cycle efficiency. Joule-Brayton cycle.

Structure of a nucleus, Yukawa potential. Nuclear fission. Thermallisation of neutrons. Suitable moderator material. Suitable isotopes for nuclear fission. Parameters defining burn rate of nuclear fuel. Parameters defining geometrical shape of the nuclear fuel. Methods of introducing time delay in the flux of neutrons for the reactor control. Main types of water-cooled nuclear reactors.

Nuclear fusion. Fuel for nuclear fusion. Energy break-even and the Lawson criterion. Magnetic confinement fusion, TOKAMAK, pinch effect in fusion plasma, theta-pinch and z-pinch. Stellarator. Inertial confinement fusion. Catalysed fusion reactions by Weizsacker and Bethe.

Fundamentals of photon statistics and its derivation from the Fermi function. Planck’s law. Stefan-Boltzmann law. Kirchhoff’s law. Temperature of the Sun’s surface.

Physics and structure of a semiconductor diode. I(V) equation of a diode. Derivation of equations of transport phenomena in a p-n junction. Solar photovoltaic cell as a diode. I(V) characteristics or a diode with- and without illumination. Fill factor. Temperature effects in solar cells and their quantification.

Equivalent circuit of a solar cell. Schockley-Queisser limit. Advanced solar cells, tandem solar cells. Energy payback of a solar cell. Solar cells that are not based on silicon.
Production of electricity from solar thermal power and its fundamentals. Concentration of solar radiation. Solar troughs, Fresnel concentrators, solar dish concentrator.

Assessment	**Weighting**
Examination	100%

PYU44PP2 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%

PYU44PP5 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%

PYU44T10 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%

PYU44T20 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**
Continuous Assessment	100%

PYU44TP2 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%