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

School of Physics
Undergraduate Handbook 2026/27



Athena SWAN Silver Award
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300
Tercentenary of Physics in Trinity | 1724 – 2024

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 2026/27

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

Physics,

Physics and Astrophysics,

Nanoscience

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

Theoretical Physics

Cover page: Teaching Notes in the Fitzgerald Lecture Theatre

Table of Contents

Introduction 4
General School Information 5
Email Protocols for Students 9
Programme Overview 10
Graduate Attributes 14
Programme Regulations (including Progression Regulations) 15
Progression and Awards 17
Derogation from progression regulations applying to accredited Physics programmes 17
Attendance requirement of the School of Physics: 20
Academic Integrity 23
College regulations on Academic Integrity 24
School of Physics restrictions on Artificial Intelligence and Generative AI 25
Artificial Intelligence and Generative AI: School of Physics regulations 27
Example School of Physics Coversheet Declaration: 28
Script Viewing Process 29
Junior and Senior Fresh Physics 31
Junior Fresh Theoretical Physics 32
Senior Fresh Theoretical Physics 33
Junior Sophister Physics 35
Junior Sophister Theoretical Physics 37
Junior Sophister Physics and Astrophysics 39
Junior Sophister Nanoscience 41
Senior Sophister Physics 43
Senior Sophister Theoretical Physics 46
Senior Sophister Physics and Astrophysics 48
Senior Sophister Nanoscience 50
Information on Academic Resources 53
Dignity, Respect and Consent 54
Emergency Contacts 55
Health and Safety 55
Student Supports 57
Index of Modules 66

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. 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 with combinations of transferable skills unique to our degrees. Our graduates are thus in demand for positions in research both here and overseas, and for a very wide range of jobs in industry and commerce.

A note on this handbook

This handbook applies to Sophister students in the TR063 Physical Sciences course 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. Any Junior and Senior Fresh students taking Physics in TR060 Biological and Biomedical Sciences, TR061 Chemical Sciences, TR062 Geosciences, or TR063 Physical Sciences should consult the relevant Handbook for their courses, which are 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 Junior Sophister - Science | Trinity College Dublin (tcd.ie).

Please note that this handbook only provides information regarding courses, modules, exams etc. within 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 and their course handbooks.

The information provided in this handbook is accurate at time of preparation. Any necessary revisions or changes will be notified to students via email. 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 in the

University Calendar will prevail, excepting where the General Regulations defer to the School or Programme Handbook.

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, in Physics in 1951, for his part in the 1932 transmutation of lithium into two alpha particles. In 2024 a series of events celebrating the Tercentenary or 300-year history of physics in Trinity College Dublin were held. See https://www.tcd.ie/physics/300/

Facilities

An elegant, dedicated Physical Laboratory building was completed in 1906, now named the Fitzgerald building, and with the Sami Nasr Institute for Advanced Materials (SNIAM), which was completed in 2000, these house the central part of the School today. The School, which is based in these buildings and in CRANN, provides excellent modern facilities for teaching and research for a very lively community of over 200 physicists, technical and support staff, including 30 academic staff, approximately 60 postdoctoral fellows and 125 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 Research Ireland and/or the European Research Council. 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 Advanced Microscopy Laboratory (AML). 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

Professor Jonathan Coleman, Head of School
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Professor Evan Keane, Junior Fresh Year Head
Contact: Evan.Keane@tcd.ie

Professor Hongzhou Zhang, Senior Fresh Year Head (on sabbatical for Semester 1)
Contact: hozhang@tcd.ie

Professor Luca Matra, Senior Fresh Year Head (Semester 1)
Contact: lmatra@tcd.ie

Professor Igor Shvets, Junior Sophister Year Head
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Professor Paul Eastham, Senior Sophister Year Head
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Contact: stamenp@tcd.ie

Professor Charles Patterson, Physics Moderatorship Course Coordinator
Contact: Charles.Patterson@tcd.ie

Professor Neale Gibson, Physics & Astrophysics Moderatorship Course Coordinator
Contact: n.gibson@tcd.ie

Professor Chris Batchelor-McAuley, Nanoscience Moderatorship Course Director
Contact: npcam@tcd.ie

Professor David O'Regan, Theoretical Physics Course Coordinator in Physics
Contact: David.O.Regan@tcd.ie

Professor Mauro Ferreira, Visiting Student Coordinator
Contact: ferreirm@tcd.ie

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School Office Staff – Undergraduate Administration:

Ms. Úna Dowling
Tel: 896 1675, e-mail: dowlingu@tcd.ie

Ms. Rashima Sharma
Tel: 896 1675, e-mail: sharmar3@tcd.ie

Global Officer

Dr. Ning Jiang
E-mail: njiang@tcd.ie

Key Locations:

School Office
SNIAM Room 1.25 (First Floor)
Tel: +353 (0)1 896 1675
https://www.tcd.ie/physics/

Map links:
https://www.tcd.ie/Maps/map.php?q=SNIAM
https://goo.gl/maps/Vv7ipCrp4NeEXH3L7

JF / SF / JS Teaching Laboratories
First Floor, SNIAM

JS Nanoscience Teaching Laboratory
Ground Floor, SNIAM

Physics Computer Lab
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.

Science Course Office
27 Westland Row
Trinity College Dublin
Location: Panoz/ Watts Building opposite the Chemistry labs
science@tcd.ie
https://www.tcd.ie/science/

Academic Registry
Watts Building
Trinity College Dublin
academic.registry@tcd.ie
https://www.tcd.ie/academicregistry/

Virtual Learning Environment
https://tcd.blackboard.com/ or https://mymodule.tcd.ie/

Email Protocols for Students

Check E-mails: Every student has a TCD email address. You are expected to check this regularly and to read and act promptly upon all messages sent to you. You should check your College e-mail daily during teaching term as it will be used to communicate important information.

If away from Trinity on Erasmus or on an exchange you should still check your TCD mail periodically.

Sending e-mails: E-mail is a useful way of contacting lecturers and administrators with queries about course work, to arrange an appointment, or to request a letter of recommendation. E-mail within College is essentially work-related, so it is appropriate to be relatively formal.

Subject Lines: When sending e-mail, please fill in the subject line so as to indicate the purpose of the e-mail. This will help the recipient to answer your query and to recover the e-mail subsequently if necessary.

Forms of address: As a courtesy, e-mails should address recipients by name. If you are using titles (Ms.; Mrs.; Mr.; Dr; Professor) these should be accurate. If you are unsure as to a name or title this can be checked in this handbook.

Introducing yourself: If you are writing to a member of staff for the first time, make sure your complete name and student number appears somewhere in the e-mail. If your e-mail relates to a particular module, include the module code and title.

Expectations re response: Responses to e-mail should only be expected during normal working hours, i.e. from 9.00am to 5.00pm, Monday to Friday. You should not expect academic or administrative staff to respond to your e-mails at weekends or when College is closed during holiday periods.

Be secure: Beware of phishing, never divulge your account details to non-TCD addresses and do not click on links from unknown sources.

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 as do Engineering students.

The four Moderatorships are outlined with relevant CAO course code and the full course name.

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 capstone research project (20 credits) 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 capstone research project (20 credits) either in Astrophysics or Physics. Projects in either Astrophysics or Physics take place in one of the Astrophysics or Physics 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 – Theoretical Physics

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 capstone project (20 credits) 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 - entry also via TR061 – Chemical 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), Chemistry (20 credits in 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 classes 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 capstone research project (20 credits). In many cases, when conditions allow, 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:

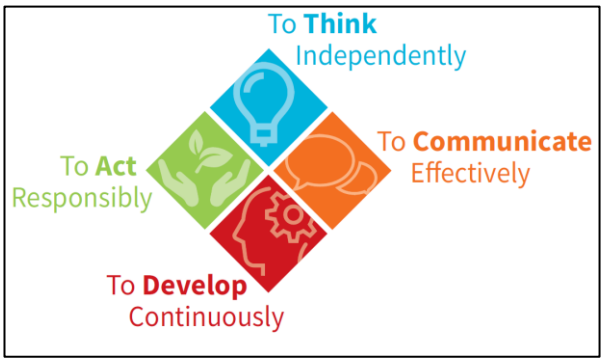
a) Articulate in written and oral form a foundation level of knowledge and understanding of Physics, Chemistry and Mathematics
b) Apply key concepts in Physics and Chemistry and key concepts in the Physics and Chemistry of Materials for the design of materials with novel properties
c) Design, perform, 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.

Graduate Attributes

The Trinity Graduate Attributes represent the qualities, skills and behaviours that you will have the opportunity to develop as a Trinity student over your entire university experience, in other words, not only in the classroom, but also through engagement in co- and extra-curricular activities (such as summer work placements, internships, or volunteering).

The four Trinity Graduate Attributes are:

- To Think Independently
- To Act Responsibly
- To Develop Continuously
- To Communicate Effectively



Why are the Graduate Attributes important?

The Trinity Graduate Attributes will enhance your personal, professional and intellectual development. They will also help to prepare you for lifelong learning and for the challenges of living and working in an increasingly complex and changing world.

The Graduate Attributes will enhance your employability. Whilst your degree remains fundamental, also being able to demonstrate these Graduate Attributes will help you to differentiate yourself as they encapsulate the kinds of transversal skills and abilities, which employers are looking for.

How will I develop these Graduate Attributes?

Many of the Graduate Attributes are 'slow learned', in other words, you will develop them over the four or five years of your programme of study.

They are embedded in the curriculum and in assessments, for example, through undertaking independent research for your final year project, giving presentations and engaging in group work.

You will also develop them through the co-curricular and extra-curricular activities. If you help to run a club or society you will be improving your leadership skills, or if you play a sport you are building your communication and team-work skills.

Programme Regulations (including Progression 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'. In the Fresher years there is a derogation from the General Regulations, whereby a minimum threshold for examination or laboratory performance is required. This will supersede the 'qualified pass' regulation described above. A detailed discussion of this is in the section on Progression below.

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.

Students who have failed a module, are reassessed in the failed components of a module. In addition, those Fresher students who have not achieved the minimum threshold in the designated examination or laboratory components, have a 'qualified fail' and are reassessed in those components.

Scholarships, Prizes and Awards

Fitzgerald Medal and prize in Theoretical Physics – A FitzGerald medal will be awarded annually on the recommendation of the Head of the School of Physics to a candidate who obtains a first-class moderatorship in the Theoretical Physics degree and who has shown outstanding merit. In exceptional circumstances a second medal may be awarded.

Coey Medal and prize in Physics – A Coey Medal (1925 – 2025) medal will be awarded annually on the recommendation of the Head of the School of Physics to the candidate who obtains a first-class moderatorship in Physical Sciences – Physics and who has shown outstanding merit. In exceptional circumstances a second medal may be awarded.

Tercentenary of Physics in Trinity Medal and prize in Physics and Astrophysics – A Tercentenary of Physics in Trinity (1724 – 2024) medal will be awarded annually on the recommendation of the Head of the School of Physics to the candidate who obtains a first-class moderatorship in Physical Sciences – Physics and Astrophysics and who has shown outstanding merit. In exceptional circumstances a second medal may be awarded.

Walton Prize in Physics – awarded annually, on the nomination of the Head of the School of Physics, 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. The prize is awarded on the recommendation of the Director of Nanoscience

McGilp Project Prize in Physics – awarded to the student who has obtained the highest mark for the Senior Sophister project work in the Physics, or Physics and Astrophysics, moderatorship. The prize is awarded on the recommendation of the Head of the School of Physics

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.

Progression and Awards

An overview of the progression regulations within the Physics programme are detailed here. The School of Physics has specific derogations from the undergraduate progression and awards regulations within the degree programmes accredited by the Institute of Physics (IoP), the Physics, Physics and Astrophysics, Nanoscience and Theoretical Physics degrees.

Information on the general regulations for undergraduate progression and awards can be found via the following webpage: https://www.tcd.ie/academic-affairs/academic-regulations/-undergraduate-progression-and-awards/
Information in relation to all undergraduate Regulations can be found via the following: https://www.tcd.ie/academic-affairs/academic-regulations/

Derogation from progression regulations applying to accredited Physics programmes

The full text of these School of Physics derogations from the progression and award regulations can be found at: https://www.tcd.ie/academic-affairs/academic-regulations/-undergraduate-progression-and-awards/#d.en.2061101. There are derogations listed for the School of Physics under the progression and award categories of "3. Progression Threshold", and "8. Reassessment".

A detailed exposition of these derogations are presented here.

A) Minimum mark requirement and Qualified Fails in Fresher years

i. These regulations apply to the Fresher JF and SF 10 credit modules that are core to Physical Sciences (TR063) and Theoretical Physics (TR035), and which are available as Open modules to JF and SF Chemical Sciences (TR031) students.

   These modules are JF: PYU11P10, PYU11T10, PYU11P20, PYU11T20; and in SF: PYU22P10, PYU22T10, PYU22P20, PYU22T20. (This does not include PYU11F10, PYU11F20, PYU11H20).

ii. In these Fresher modules there is a minimum mark requirement of 30% separately in both the Examination component and the Laboratory component, in order for either a Pass or a Qualified Pass mark in the module to be granted. The Progression threshold is not simply an overall module mark of 40% or higher, but requires minimum marks in these components.

iii. A mark of less than 30% in either the Examination or Laboratory components leads to a Qualified Fail. A Qualified Fail requires reassessment in that component before progression to the next year can occur. Reassessment of the exam component is in the reassessment

examination period; reassessment of the laboratory component occurs before the beginning of the reassessment examination period.

iv. If a mark of less than 30% occurs or recurs in the examination or laboratory component following the reassessment period, the student cannot progress and must repeat the year. This necessarily applies to students who had deferred their first attempt at examinations to the reassessment period.

v. Students who fail a module with a module mark of <40%, but >=35% are not eligible for Pass by Compensation, or a Qualified Pass, if either of the examination or laboratory components is less than 30%.

vi. For context only, two points are repeated from the general undergraduate progression and awards regulations. The first is that as much as 10 credits can be eligible for a Qualified Pass or a pass by compensation with marks of 35% or higher, provided the other 50 credits of module marks are 40% or higher, and there is an overall pass. Secondly, students who fail a given module can only be reassessed in failed components of the module.

B) Capping of reassessed components in reassessment session in Fresher and Sophister years

In reassessments, a cap (maximum mark) of 60% will apply to

i. All the reassessed components for core Junior Fresh and Senior Fresh Physics modules delivered as part of the Physical Sciences and Theoretical Physics courses (and available to students in the Chemical Sciences course as Open modules) which are listed above in A(i).

ii. All reassessed components of all modules in the Sophister years (except Trinity Electives) within the four accredited degree programmes Physics, Physics & Astrophysics, Nanoscience, and Theoretical Physics, irrespective of the owning School. Accreditation of these degree programmes is by the Institute of Physics (IoP).

The abovementioned capping will apply to re-assessed components of the affected School of Physics (PYU code) modules irrespective of the degree stream of the student, registration or visiting student status, or year of first admission. The Sophister PYU modules are not available to any other non-accredited Sophister degree programmes.

Re-assessment capping does not apply to deferred 1st attempts at assessment.

Rationale for capping reassessments in Physics degrees

The capped reassessments are required of College and the School of Physics by the Institute of Physics (IoP) for continued accreditation of our four degree programmes in Physics, Physics with Astrophysics, Nanoscience and Theoretical Physics. This is to ensure the continued integrity and quality of our degree programme, results and outcomes. It should be noted that uncapped resits are not the norm in other universities either in Ireland or elsewhere that have degrees accredited by the IoP, where the usual capping level of reassessed components or exams is at 40%. The reassessment capping level agreed with the IoP is a compromise between

ensuring the continued quality of our degree recipients and their degree results against the intended purpose and rationale underpinning uncapped resits elsewhere in College. That policy was to encourage students to achieve the intended learning outcomes in the reassessment by engaging fully with learning in order to do their best, and this is still possible as students are rewarded for doing more than the minimum required to pass.

Examples in Junior Fresh or Senior Fresh of Qualified Fails:

Example of a qualified fail at the first attempt:

- Student A in their Semester 1 JF module obtains a mark of 60% in their labs, 80% in their assignments but 25% in their examination with weightings of 30%, 10% and 60% respectively. Their module mark is thus (60*0.3) + (80*0.1) + (25*0.6) = 18+8+15 = 41%. This however is a Qualified Fail as they obtained a mark <30% in their examination. They do not pass the module and must present for reassessment.
- Student B in their Semester 2 JF module obtains a mark of 60% in their labs, 80% in their assignments but 20% in their examination with weightings of 30%, 10% and 60% respectively. Their module mark is thus (60*0.3) + (80*0.1) + (20*0.6) = 18+8+12 = 38%. This is a Fail mark in the module, and this mark is not eligible to be a Qualified Pass as this student obtained a mark <30% in their examination. They do not pass the module and must present for reassessment. Compensation rules otherwise apply to module marks >=35% provided 50 credits of modules have achieved a pass mark and no more than 10 credits of module are equal to or above 35% and none are below 35%, provided that the annual average mark is 40% or higher.

Example of a qualified fail at the second attempt:

- If either Student A or Student B above obtained those marks in their reassessment examination at their second attempt, i.e. obtaining a Qualified Fail or being ineligible for a Qualified Pass, they must repeat the year. Instead of a full repeat year on-books there is the possibility to apply through their Tutor to take the following year as an Off-Books student taking Assessment in this module, if they are eligible to do so.

Example of a capped reassessment:

- Student C in their Semester 2 SF module obtains a mark of 50% in their labs, 80% in their assignments but 20% in their examination with weightings of 30%, 10% and 60% respectively. Their module mark is thus (50*0.3) + (80*0.1) + (20*0.6) = 15+8+12 = 35%. This is a Fail and they are reassessed in the failed component, and not eligible for compensation or a Qualified Pass as they had a mark <30% in their examination.
  In their reassessed exam, having engaged at length with the material they perform well in their examination and would obtain a mark of 80%. This exam mark component is capped at 60% while the other component marks remain as they were.

- The final mark is thus calculated as: (50*0.3) + (80*0.1) + (60*0.6) = 15+8+36 = 59% for the module.

Attendance requirement of the School of Physics:

All students must attend College in person during the teaching term. They must take part fully in the academic work of their class throughout the period of their course. This is understood to mean attendance at all lecture and tutorials. The requirements for attendance at lectures and tutorials in the School of Physics is thus a matter for the student.

Attendance at laboratories in the School of Physics is compulsory for students in all years. Permission to be absent must be sought at least one week in advance. Permission for absence in retrospect can be granted e.g. for medical of family reasons, on a case-by-case basis, and submission of the appropriate absence from College form, and informing the laboratory supervisor as soon as possible.

Non-satisfactory attendance:

Non-attendance of 50% of laboratories or greater, which is otherwise unexplained by illness, exigent circumstances or by permission sought in advance, can result in a student being deemed non-satisfactory in their attendance.

Such non-satisfactory attendance falls under section §24 and §25 of the University Calendar Part II Undergraduate Studies Part B1 'General Regulations and Information'. A link to policy is at: https://www.tcd.ie/academicregistry/student-cases/non-satisfactory-attendance/

Students whose attendance is reported as non-satisfactory may be required by the Senior Lecturer to repeat the year. This request will be made by the School of Physics in January, in advance of the commencement of Hilary term (for cases of non-satisfactory attendance in Michaelmas term) or two weeks prior to the publication of annual examination results (for cases of non-satisfactory attendance in Hilary term).

The relevant Calendar regulations are replicated here.

Calendar Part II regulations on Attendance, Non-Satisfactory Attendance and Exceptions

Attendance §17 – 19

17 All students must begin attendance at the College not later than the first day of teaching term, unless they have previously obtained permission from the Senior Lecturer through their tutor.

18 All Students must attend College in person during the teaching term. They must take part fully in the academic work of their class throughout the period of their course. Lecture timetables are published through my.tcd.ie and/or elsewhere, as appropriate, before the beginning of Michaelmas teaching term. The onus lies on students to inform themselves of the dates, times and venues of their lectures and other forms of teaching by consulting these timetables.

19 The requirements for attendance at lectures and tutorials vary between the different faculties, schools and departments. The school, department or course office, whichever is

relevant, publishes its requirements for attendance at lectures and tutorials in handbooks, and/or elsewhere, as appropriate. () Attendance at lectures and practical classes is compulsory for students in all years of () any programme where it is indicated as a requirement in handbooks or elsewhere.

() indicates text irrelevant to this handbook or programme being omitted.

Non-satisfactory attendance §24 – 25

24 All students must fulfil the programme and/or module requirements of the school, department or programme, as appropriate, with regard to attendance.

25 At the end of the teaching term, students who have not satisfied the school, department or programme requirements, as set out in Calendar §§19 and 24 [and described in the School of Physics handbook] above, may be reported as non-satisfactory in their attendance for that term. The Procedures for completing a report on Non-Satisfactory Attendance (NSA) should be followed. These can be accessed on the College website at www.tcd.ie/academicregistry/studentcases, where a copy of the NSA form can also be found.

Students whose attendance is reported as non-satisfactory may be required by the Senior Lecturer to repeat their year. If this consequence is requested by a School, a fully completed non-satisfactory attendance (NSA) form must be received by the Senior Lecturer via Student Cases no later than two working weeks prior to the commencement of Hilary term (for cases of non-satisfactory attendance in Michaelmas term) or two weeks prior to the publication of annual examination results (for cases of non-satisfactory attendance in Hilary term).

Concerning special circumstance exemptions, and/or disability or illness §20 – 23

20. In special circumstances exemption from attendance at lectures for one or more terms may be granted by the Senior Lecturer; application for such exemption must be made in advance through the tutor. Students granted exemption from attendance at lectures are liable for the same annual fee as they would pay if attending lectures. Students thus exempted must perform such exercises as the Senior Lecturer may require. If these exercises are specially provided, an additional fee is usually charged.

21 Students who in any term have been unable, through illness or other unavoidable cause, to attend the prescribed lectures satisfactorily, as determined by the relevant School, department or programme, may be granted credit for the term by the Senior Lecturer and must perform such supplementary exercises as the Senior Lecturer may require. Such requests will be only considered in extraordinary circumstances and should be made by the student's tutor to the Senior Lecturer (via Student Cases) and only after consulting the general and more detailed school or course regulations regarding absence from lectures or examinations through illness.

22 Students who are unable to attend lectures (or other forms of teaching) due to disability should immediately contact the Disability Service to discuss the matter of a reasonable accommodation. Exceptions to attendance requirements for a student, on disability grounds,

may be granted by the Senior Lecturer following consultation with the student's school, department or course office, and the Disability Service.

23 Students who find themselves incapacitated by illness from attending lectures (or other forms of teaching) should immediately see their medical advisor and request a medical certificate for an appropriate period. Such medical certificates should be copied to the school, department or course office, as appropriate, by the student's tutor.

Academic Integrity

Academic integrity can be described as a commitment to, and compliance with: *"ethical and professional principles, standards, practices and consistent system of values, that serve as guidance for making decisions and taking actions in education, research and scholarship" (NAIN Lexicon, p.3)* [1]

Trinity is committed to upholding academic integrity, and recognises that it underpins all aspects of university life, including all activities relating to research, learning, assessment, and scholarship. Trinity therefore considers academic misconduct to be serious and academically fraudulent and an offence against academic integrity that is subject to the Trinity procedures in cases of suspected misconduct.

Plagiarism is classed as Academic Misconduct and is considered a serious offence in Trinity and carries a range of penalties depending on the severity of the offense. Plagiarism is using someone else's ideas, charts, concepts, code or words in your assignments and using them as if they were your own, and without giving credit to the actual author. The College, and School of Physics in addition interprets the use of Generative AI in submission of writing or coding assignments while passing this off as if the work was your own as a violation of academic integrity. Writing with academic integrity, that is, not plagiarising ideas or representing work you have not done yourself as your own, is a key expectation of Trinity students.

The emphasis should thus be on good academic practice and the development of your own academic writing skills or coding skills. To ensure that you have a clear understanding of good academic practice and to help you understand and avoid academic misconduct while practising your academic writing skills, there is a repository of information and extensive introduction about Academic Integrity at https://libguides.tcd.ie/academic-integrity .

The ways in which Trinity deals with cases of Academic Misconduct are detailed at: https://www.tcd.ie/academic-affairs/academic-integrity/ which shows the Academic Misconduct Flowchart and links to the Academic Misconduct Procedures.

- Academic Integrity Introduction (formerly Avoiding Plagiarism): https://libguides.tcd.ie/academic-integrity
- Ready Steady Write tutorial: https://libguides.tcd.ie/academic-integrity/ready-steady-write
- General Coversheet declaration: https://libguides.tcd.ie/academic-integrity/declaration – now includes a required acknowledgement of any use of GenAI, per the guidelines below, **when GenAI is permitted** (See each School of Physics module in Blackboard).
- Guidance for acknowledging the use of GenAI – when permitted in a module – is located at: https://libguides.tcd.ie/gen-ai.
- Consequences of academic misconduct: https://www.tcd.ie/academic-affairs/academic-policies/academic-integrity/consequences-of-academic-misconduct/

[1] National Academic Integrity Network – Lexicon at https://www.qqi.ie/what-we-do/engagement-insights-and-knowledge-sharing/national-academic-integrity-network

Correct referencing is essential when crediting your sources and avoiding plagiarism. Your course handbook will tell you what style of referencing you should use in your assignments so be sure to check that out before you start any assignments. You will waste a lot of time if you have to redo your references.

College regulations on Academic Integrity

The School of Physics strictly implements Trinity College Dublin's policy on academic integrity.

Academic Integrity (excerpt from the College Calendar, Part II Undergraduate Studies) available from: https://www.tcd.ie/calendar/undergraduate-studies/

96 *General*

It is clearly understood that all members of the academic community use and build on the work and ideas of others. However, it is essential that we do so with integrity, in an open and explicit manner, and with due acknowledgement.

Any action or attempted action that undermines academic integrity and may result in an unfair academic advantage or disadvantage for any member of the academic community or wider society may be considered as academic misconduct. Examples of academic misconduct can be found in the curriculum glossary.

97 The use of Generative Artificial Intelligence (GenAI) is permitted unless otherwise stated in programme handbooks. Where the output of GenAI is used in a document or work output, this usage should be acknowledged and appropriately cited, as per Library guidelines on acknowledging and referencing GenAI. Where restrictions are applied around the use of GenAI in particular modules, those restrictions must be explicitly stated in modules descriptions in Blackboard Ultra and/or in programme or module handbooks.

For further guidance, see the Trinity GenAI statement (www.tcd.ie/media/tcd/academic-affairs/pdfs/College_Statement_on_GenAI_v2_2026.pdf).

98 *Academic misconduct in the context of group work*

Students should normally submit assessments and/or examinations done in co-operation with other students only when the co-operation is done with the full knowledge and permission of the lecturer concerned. Without this permission, submitting assessments and/or examinations which are the product of collaboration with other students may be considered to be academic misconduct.

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, or that any other academic misconduct has taken place. In order to avoid academic misconduct 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.

Should a module co-ordinator suspect academic misconduct in a group assignment, the procedure in cases of suspected academic misconduct must be followed for each student.

99 *Avoiding academic misconduct*

Students should ensure the integrity of their work by seeking advice from their module co-ordinator, tutor or supervisor on avoiding academic misconduct. All schools and disciplines 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 academic misconduct is available at https://libguides.tcd.ie/academic-integrity.

100 *Procedure in cases of suspected academic misconduct*

If academic misconduct as referred to in §96 above is suspected, the procedure in cases of suspected academic misconduct, available at https://www.tcd.ie/teaching-learning/academic-affairs/academic-integrity/ must be followed.

The case may be referred to the Junior Dean if:

(i) the facts of the case are in dispute;

(ii) the regulations of the College were not properly applied in the student's case;

(iii) the Director of Teaching and Learning (Undergraduate), or designate, forms the view that that the consequences provided for under the academic misconduct procedure are inappropriate given the circumstances of the case.

The Junior Dean will interview the student and may implement the procedures as referred to under CONDUCT AND COLLEGE REGULATIONS §2. Nothing provided for under the procedure in cases of suspected academic misconduct diminishes or prejudices the disciplinary powers of the Junior Dean under the 2010 Consolidated Statutes.

School of Physics restrictions on Artificial Intelligence and Generative AI

The College Calendar in §97 above, allows Schools to regulate and impose restrictions in particular modules for School of Physics students. the College Statement on Artificial Intelligence and Generative AI in Teaching, Learning, Assessment & Research (2026) recognises that appropriate uses of AI and GenAI tools vary across academic disciplines, Schools will have flexibility to customise their own discipline-specific practices in line with this institutional statement, other institutional policies as they develop, and national and international regulation.

It is important to the School of Physics that academic integrity in assessments is not compromised and the development of skills and knowledge that are critically important to the learning outcomes of our modules and of our degree programmes as a whole are also not compromised. There are use cases for GenAI within physics education, but these should not be used to substitute for critical thinking, or engagement with materials, but instead to aid the development of the relevant skills or of the relevant knowledge of the student. Students are instead asked to use GenAI judiciously; they could begin so by asking GenAI on guidelines how to aid their development.

Guiding principle: A simple guiding principle would be that **one should only ask a question of a GenAI prompt that one would be prepared to ask of your lecturer**. Do not ask GenAI for solutions; but ask instead for guidance to complement learning and understanding, e.g. to explain the next step in a derivation on a step-by-step basis and/or the underlying physical reasons for that step or substitution, or to explain a specific term in an equation and its physical interpretation.

Warning: GenAI tools do not store facts and knowledge, rather they generate outputs based on **probabilities**. Thus, GenAI is prone to making factual errors (called **hallucinations**) which are, nonetheless, very convincingly presented. This is where academic/professional judgement and domain expertise are very important. If you are using GenAI, you need to double-check the information it is giving you as it may present information which is simply not true! Therefore, it is crucial for any user to **fact-check** any output from a GenAI tool**.**

Students are advised to read the College Statement on Artificial Intelligence and Generative AI in Teaching, Learning, Assessment & Research but some items are highlighted here.

Guiding principles and values underpinning the use of AI and GenAI in Trinity:
Namely: **Transparency and Honesty**, **Responsibility and Accountability**, **Respect**, and **Innovation**.

Access to GenAI Technologies at Trinity:

Trinity students can access **Microsoft Copilot Chat** through their institutional Microsoft 365 account. When users sign in with their Trinity credentials, Copilot Chat applies Microsoft's enterprise data protection controls, indicated by a green shield on screen. This means that **all prompts and responses stay within the Microsoft 365 service boundary, are encrypted, are not stored and are not used to train underlying models.** This ensures the service is covered under Trinity's agreed terms with Microsoft, including data protection and data-processing arrangements.

Be aware when permitted to use GenAI within specific School of Physics modules assessments:

1. At all times when GenAI is permitted in a specific module and for a specific exercise, and where the output of GenAI is used to inform a student's document or work output, this usage should be acknowledged and appropriately cited as per Library guidelines on acknowledging and referencing GenAI.
2. From an academic integrity perspective, if a student generates content from a GenAI tool and submits it as his/her/their own work, **it is considered plagiarism which is defined as academic misconduct**. If a sentence or quotation from GenAI content is used by a student in their academic work, **it must be referenced**.
3. Note any long verbatim quotation (e.g. more than one paragraph), even with citation, may be considered inappropriate or poor practice in student assessment documents and publications.
4. Cases of plagiarism are considered under College Academic Misconduct Procedures and College's Academic Integrity Policy., which is defined as academic misconduct in accordance with College Academic Integrity Policy.

Artificial Intelligence and Generative AI: School of Physics regulations

The following applies for all modules in the four recognised degree programmes within **Physical Sciences** and **Theoretical Physics**: these degrees being **Physics**, **Physics and Astrophysics**, **Nanoscience** and **Theoretical Physics**; it also applies to the service teaching modules delivered by the School of Physics in other degree programmes.

This is a general statement of the use of GenAI within School of Physics modules, and will apply where there is not a specific instruction on a module-by-module basis.

In the School of Physics the use of GenAI is **not permitted** for the production or submission of any Continuous Assessment work in the SoP, unless specifically allowed in the module, limited to specified exercises or sub-parts thereof within the module, as instructed by the lecturer and in full adherence to the guidelines given for the exercise, *which would include the cited Library guidelines on acknowledging and referencing GenAI*. The use of GenAI outside of these narrow constraints and guidelines would, within the SoP, be considered plagiarism and constitute academic misconduct. Note that this applies to python computer code as well as to written text.

The use of GenAI to guide or refine a students own written responses to continuous assessment is permitted by the School of Physics, so long as this used to provide guidance to the student, advises on corrective actions, and is not used as the basis for any written submission constituting only a very minor fraction of the text.

Module and/or exercise specific guidelines will be added below this general statement within each Blackboard module.

The School of Physics reserves the right to refine this information.

Example School of Physics Coversheet Declaration:

The module specific version of this must be attached to submitted work, signed by the student:

"Declaration: I have read and understood the academic integrity provisions in the General Regulations of the University Calendar for the current year, found at http://www.tcd.ie/calendar. I have also read and understood **(i)** the programme-level permissions regarding the use of GenAI in this assessment task, outlined in the School of Physics undergraduate programme handbook that relates to this assessment, and/or **(ii)** any module-level or assignment-level permissions that relate to this specific module or this specific assignment, which are outlined in the module descriptions in the Blackboard VLE.†

Where I have used the output of GenAI in my work, I have acknowledged its use in my work and understood the guidance, located at: https://libguides.tcd.ie/gen-ai.

I have also read and understood the Academic Integrity guide located at https://libguides.tcd.ie/academic-integrity and completed the 'Ready Steady Write' Tutorial on avoiding plagiarism, located at https://libguides.tcd.ie/academic-integrity/ready-steady-write.

Signed by: _____

Module exercise: _____

Dated: _____"

† Students should contact their module co-ordinator if they are unsure about the GenAI permissions that relate to this assessment within that module.

Note that there may be differing versions of the coversheet declaration that stipulates the module-level or assignment-level permissions that pertain to specific assessments in the same module, if necessary.

Script Viewing Process

All students have a right to discuss their examination and assessment performance with the appropriate members of staff. Students are entitled to view their scripts and other assessments in person when discussing their performance. For work completed during semester one, students should note that all results are provisional until moderated by the court of examiners in Trinity term. In Trinity term, students' performance cannot be discussed with them until after the publication of the end-year results. The School of Physics allows students to firstly view scripts and then seek an appointment to then obtain feedback on the examination script from the examiner. To preserve the integrity of the examination script the process below is adhered to rigidly.

Script Viewing Process in the School of Physics

- Initial script viewings take place in the School Office. You should contact the School Administration Team to arrange a suitable date / time. Please note that due to the large volume of requests that are received immediately after publication of examination results these can take time to organise.
- Scripts can only be viewed by the individual student concerned. You cannot have someone else represent you.
- Scripts must be viewed in person only. They cannot be viewed online.
- Have your student ID ready to show.
- You cannot write on the scripts.
- You cannot take photographs of the scripts.
- You cannot take notes.
- You *can* contact any relevant examiners later if you wish. They will be able to go through your script with you to provide further feedback.

Regulations surrounding re-check/re-mark of examination scripts

- The full set of College regulations are outlined in the College Calendar (page 39).
- The information below is taken from the Senior Tutor's Office website (https://www.tcd.ie/seniortutor/students/undergraduate/):

First of all, once the results are published you should discuss your examination/assessment performance with the examiners to understand why a specific mark was awarded.

Please note that these consultations are not an opportunity to negotiate an increase of your marks. Lecturers cannot change any marks once they have been approved by the Court of Examiners.

You are entitled to view your script when discussing your examination or assessment.

If you are still unhappy with your result and you have reason to believe that:
a. The grade is incorrect because of an error in calculation of results,
b. The examination paper contained questions on subjects which were not part of the course prescribed for the examination, or

c. Bias was shown by the examiner in marking the script,

- In the case of a. above, the School will recalculate your mark and request permission for the Senior Lecturer's Office for a mark change.
- In the case of either b. or c. above, you should contact your Tutor to discuss the situation. Your Tutor can request a re-mark. Please note that ground b. applies to the class as a whole, not to individual students. Please also note that ground c requires evidential proof that bias from the examiner has occurred in marking the script.

Junior and Senior Fresh Physics

Physical Sciences Students (Junior and Senior Fresh)

There is a separate Course handbook available for each Fresher year in the Physical Sciences which are available at: https://www.tcd.ie/science/undergraduate/tr063-physical-sciences/ For the Junior Fresh Physical Sciences see: https://www.tcd.ie/science/undergraduate/tr063-physical-sciences/junior-fresh/ and for the Senior Fresh Physical Sciences see: https://www.tcd.ie/science/undergraduate/tr063-physical-sciences/senior-fresh/.

Please consult the appropriate Physical Sciences Course handbook for the Junior Fresh and Senior Fresh years in Physical Sciences.

Regulations on Progression and Reassessment specific to the Fresher years in Physical Sciences are detailed in this School of Physics Undergraduate Handbook, as well as in the two Physical Sciences Course handbooks.

Physical Sciences Students (Junior and Senior Sophister)

For details on progression to the Junior Sophister year in the Physical Sciences course and for entry into one of the three Moderatorships accessible from Physical Sciences, namely the **Physics** Moderatorship, the **Physics and Astrophysics** Moderatorship and the **Nanoscience** Moderatorship, then see the Physical Sciences TR063 Sophister Programme Booklet. This is at: https://www.tcd.ie/science/undergraduate/tr063-physical-sciences/junior-sophister/

The details of the allocation of places into these Moderatorships is detailed in the Sophister Programme booklet and at that webpage.

Information on the course structure in both Junior and Senior Sophister years is in the Physical Sciences Sophister Programme booklet, inclusive of the detailed Optional module choices in these years that are available to students.

Regulations on Reassessment specific to the Sophister years in all the Physical Sciences degree programmes are detailed in this School of Physics Undergraduate Handbook, as well as in the Physical Sciences Sophister Programme booklet.

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

Semester 1 – 45 lectures, practical laboratory, online assignments & small group tutorials

PYU11T20 Physics for Theoretical Physics – 10 credits

Semester 2 – 47 lectures, practical laboratory, online assignments & small group tutorials

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

JF Practical Laboratory Classes – Semester 1, Semester 2

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

JF Group Tutorials – Semester 1, Semester 2

Every student is assigned to a tutorial group with other students. The tutorials will be delivered on the topics in the JF year by academic members of staff or by the lecturers of those topics.

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 a Qualified Pass, according to the rules of the course they are taking, or present for reassessment in the module.

Important Note on Examinations and Assessments

There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement. A mark of less than 30% in either of these Examination or Laboratory components leads to a Qualified Fail, and requires reassessment, supplemental examination or a repeat of the year. Further, any reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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
Semester 1 – 48 lectures, practical laboratory, project, online assignments and tutorials

PYU22T20 Modern Physics for Theoretical Physics – 10 credits
Semester 2 – 52 lectures, practical laboratory, online assignments and tutorials

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

Practical Laboratory Classes – Semester 1, Semester 2

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. Students have oral interviews on these experiments and reports with an academic.

Group Study Projects – Semester 1

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 Semester 1.

Full Cohort Tutorials – Semester 1, Semester 2

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 a Qualified Pass or present for reassessment in the module.

Important Note on Examinations and Assessments

There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement. A mark of less than 30% in either of these Examination or Laboratory components leads to a Qualified Fail, and requires reassessment, supplemental examination or a repeat of the year. Further, any reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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
Semester 1 – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P03 Condensed Matter I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P04 Condensed Matter II – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33P15 Atomic Physics and Statistical Thermodynamics – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33PP3 JS Physics Laboratory – 10 credits
Semester 1 and Semester 2 – 20 lectures/11 laboratories

PYU33PP4 JS Physics Laboratory – 5 credits
Semester 2 – 7 laboratories

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

PYU33A03 Stellar and Galactic Structure – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33A17 Astrophysics Techniques – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P07 – Experimental Techniques – 5 credits
Semester 2 – 30 lectures/tutorials

At least One Trinity Elective Module – 5 credits

Either in Semester 1 or Semester 2, 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, e.g., of PYU33C01 which is assessed entirely by continuous assessment. 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, and factor in the marks of already passed components to calculate the module mark.

Continuous assessment of the practical modules (PYU33PP3/4) contributes 15 credits.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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, Physics, and Statistics (options may be restricted depending on the demand and conditions in a given year), totalling 30 credits per semester.

Mandatory modules:

PYU33P03 Condensed Matter I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33T15 Atomic Physics and Quantum Optics – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33TP1 Practical in Theoretical Physics – 10 credits
Semester 1, Semester 2 – 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
Semester 1 – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P04 Condensed Matter II – 5 credits
Semester 2 – 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, e.g., of PYU33C01 which is assessed entirely by continuous assessment. 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, and factor in the marks of already passed components to calculate the module mark.

Continuous assessment of the practical module (PYU33TP1) contributes 10 credits.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module, the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. Note especially that this applies to all modules in the Junior Sophister year in Theoretical Physics, irrespective of the owning School, i.e. whether it is a School of Maths, School of Physics or School of Computer Science and Statistics module with MAU, PYU and STU module codes. See section on Progression.

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
Semester 1 – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P03 Condensed Matter I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33A03 Stellar and Galactic Structure – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33A17 Astrophysics Techniques – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33AP3 JS Astrophysics Computational Laboratory – 10 credits
Semester 1, Semester 2 – 20 lectures/12 laboratories

PYU33AP4 JS Physics Laboratory – 5 credits
Semester 2 – 10 laboratories

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

PYU33P15 Atomic Physics and Statistical Thermodynamics – 5 credits
Semester 2 – 30 lectures/tutorials

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

PYU33P04 Condensed Matter II – 5 credits
Semester 2 – 30 lectures/tutorial

PYU33P07 – Experimental Techniques – 5 credits
Semester 2 – 30 lectures/tutorials

PYU33C01 – Computer Simulation I – 5 credits
Semester 1 – 30 lectures/tutorials

At least One Trinity Elective Module – 5 credits

Either in Semester 1 or Semester 2, 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, e.g., of PYU33C01 which is assessed entirely by continuous assessment. 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, and factor in the marks of already passed components to calculate the module mark.

Continuous assessment of the practical modules (PYU33AP3/4) contributes 15 credits.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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 the first semester which must be taken, both in Physics.

The following School of Physics modules are mandatory.

PYU33P01 Quantum Mechanics I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33NP3 Nanoscience Physics Laboratory – 10 credits
Semester 1 and Semester 2 – 20 Lectures and 12 laboratories

Open Modules: Students must take both specific designated School of Physics Open modules:

PYU33P03 Condensed Matter I – 5 credits
Semester 1 – 30 lectures/tutorials

PYU33P02 Electromagnetic Interactions I – 5 credits
Semester 1 – 30 lectures/tutorials

They then choose from the following other Open module from the School of Physics or alternatively an Open module from the School of Chemistry:

PYU33P04 Condensed Matter II – 5 credits
Semester 2 – 30 lectures/tutorials

One Trinity Elective Module – 5 credits
The Trinity Elective must be in Semester 2 – See https://www.tcd.ie/trinity-electives/

Chemistry modules contributing to the Nanoscience Moderatorship are listed in the Sophister Physical Sciences Programme Handbook at Junior Sophister - Science | Trinity College Dublin (tcd.ie) and on the School of Chemistry website and diagrammatically visualised at https://www.tcd.ie/physics/study/current/undergraduate/.

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. 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 reassessment assessment in the failed components of that module. Marks in the reassessment exams are calculated in the same way as in the end of semester exams, and factor in the marks of already passed components to calculate the module mark.

Continuous assessment of the practical module in Nanoscience contributes 10 credits. The balance of credits comes from Chemistry modules.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. Note especially that this applies to all modules (except Trinity Electives) within Nanoscience, irrespective of the owning School, i.e. whether it is a School of Physics or School of Chemistry module with PYU or CHU module codes This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

Senior Sophister Physics

The SS year consists of lectures, tutorials and practicals delivered in modules, as listed below. The major and sole component of the practical module (PYU44PP2) is an independent research capstone project, which is carried out ordinarily during the first 9 weeks of Semester 1, with no lectures during this period. Assessment of the project occurs in Semester 2. 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
Semester 1, Semester 2 – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44PP2 Physics Research Project – 20 credits
Semester 1, Semester 2 – Research Project

PYU44PP5 Problem Solving in Physics – 5 credits
Semester 1 – Problem Solving Tutorials and Seminars

Open Modules (PYU44P16 and PYU44A05 cannot both be selected):

PYU44P13 Magnetism & Superconductivity – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P16 Quantum Plasmonic and Metamaterials * – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P17 Energy Science– 5 credits
Semester 2 – 24 lectures/tutorials

PYU44N02 Nanoscience, Complex Fluids & Polymers – 10 credits
Semester 1, Semester 2 – 48 lectures/tutorials

PYU44T30 Electronic Transport in Nanostructures – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44C01 Computer Simulation II – 5 credits
Semester 2 – 26 lectures/tutorials

PYU44A03 Cosmology and High Energy Astrophysics * – 5 credits

Semester 2 – 24 lectures/tutorials

*** PYU44P16 and PYU44A03 cannot both be selected**

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

Note that optional modules may be withdrawn if less than five students opt for that module.

Students will be invited to choose their optional modules at the beginning of Semester 1. Please note that there will be a short window at the beginning of Semester 2 to change modules.

It will not be possible to change modules after 22nd January 2027.

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 any designated module which is assessed entirely by continuous assessment. 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 a 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.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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 take the compulsory Semester 1 5-credit module PYU44PP5 along with a 20-credit yearlong Capstone Project in either Mathematics (MAU44P00) or Physics (PYU44TP1). All remaining modules are optional, but they are subject to some restrictions.

Mandatory Taught Module (5 credits):

PYU44PP5 Problem-Solving – 5 credits
Semester 1 – Problem-Solving Tutorials and Seminars

Mandatory Project (20 credits):

PYU44TP1 Research Project – 20 credits
OR MAU44P00 Project – 20 credits

Semester 1, Semester 2 – Research project, meetings with supervisor by arrangement.

School of Physics Optional Taught Modules (PYU44P16 and PYU44A05 cannot both be selected):

PYU44T10 Condensed Matter Theory – 5 credits

Semester 1 – 24 lectures/tutorials

PYU44P12 Nuclear Structure and High Energy Physics – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44T30 Electronic Transport in Nanostructures – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P16 Quantum Plasmonic and Metamaterials * – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P17 Energy Science– 5 credits
Semester 2 – 24 lectures/tutorials

PYU44A03 Cosmology and High Energy Astrophysics *† – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44C01 Computer Simulation III – 5 credits
Semester 2 – 24 lectures/tutorials

*** PYU44P16 and PYU44A03 cannot both be selected**
Further details including learning outcomes are given for all modules in the *Index of Modules*.

Note that optional modules may be withdrawn if less than five students opt for that module.

Students will be invited to choose their optional modules at the beginning of Semester 1. Please note that there will be a short window at the beginning of Semester 2 to change modules.

It will not be possible to change modules after 22nd January 2027.

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, e.g. any designated module which is assessed entirely by continuous assessment. 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.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module, the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. Note especially that this applies to all modules in the Senior Sophister year in Theoretical Physics, irrespective of the owning School, i.e. whether it is a School of Maths or School of Physics module with MAU and PYU module codes. See section on Progression.

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 capstone research project, which is carried out ordinarily during the first 9 weeks of Semester 1, with no lectures during this period. Students select physics Open Modules totalling 10 credits.

The following modules are mandatory.

PYU44A02 Advanced Topics in Astrophysics – 10 credits
Semester 1, Semester 2 – 48 lectures/tutorials

PYU44P11 Advanced Quantum Mechanics, Nuclear Structure and High Energy Physics – 10 credits
Semester 1, Semester 2 – 48 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44PP2 Physics Research Project – 20 credits
Semester 1, Semester 2 – Research Project

PYU44PP5 Problem Solving in Physics – 5 credits
Semester 1– Problem Solving Tutorials and Seminars

Open Modules:

PYU44P13 Magnetism & Superconductivity – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P17 Energy Science– 5 credits
Semester 2 – 24 lectures/tutorials

PYU44C01 Computer Simulation II – 5 credits
Semester 2 – 24 lectures/tutorials

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

Note that optional modules may be withdrawn if less than five students opt for that module.

Students will be invited to choose their optional modules at the beginning of Semester 1. Please note that there will a short window at the beginning of Semester 2 to change modules.

It will not be possible to change modules after 22nd January 2027.

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 ordinarily be examined separately in the relevant end-of-semester examination period. 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.

Important Note on Examinations and Assessments and Reassessments in Sophister years

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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 capstone research project, which may be carried out in the School of Physics or in the School of Chemistry or 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
Semester 1, Semester 2 – 48 lectures/tutorials

PYU44NP2 Physics Research Project – 20 credits
Semester 2 – Research Project

PYU44NP5 Problem Solving in Physics – 5 credits
Semester 1 – Problem Solving Tutorials and Seminars

Open Modules (only School of Physics modules are shown):

PYU44P13 Magnetism & Superconductivity – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P05 Electromagnetic Interactions II – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P06 Modern Optics – 5 credits
Semester 2 – 24 lectures/tutorials

PYU44P17 Energy Science– 5 credits
Semester 2 – 24 lectures/tutorials

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

Note that optional modules may be withdrawn if less than five students opt for that module.

Students will be invited to choose their optional modules at the beginning of Semester 1. Please note that there will be a short window at the beginning of Semester 2 to change modules.

It will not be possible to change modules after 22nd January 2027.

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 ordinarily be examined separately in the relevant end of semester examination period. 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.

Important Note on Examinations and Assessments

In the case of students needing to be reassessed in any component of any module (except Trinity Electives), the reassessed components are capped at a maximum mark of 60%. Note especially that this applies to all modules (except Trinity Electives) within Nanoscience, irrespective of the owning School, i.e. whether it is a School of Physics or School of Chemistry module with PYU or CHU module codes This is detailed in this School of Physics Undergraduate Handbook. See section on Progression.

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.

Equality Policy

The Equality Policy, inclusive of information on Diversity and Inclusion training programmes, is detailed at https://www.tcd.ie/equality/edi-at-trinity/policy/

Information on Academic Resources

Useful websites

College website: www.tcd.ie

School of Physics website: www.tcd.ie/physics

Academic Registry: www.tcd.ie/academicregistry

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: https://www.tcd.ie/library/opening-hours/hamilton/

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

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

Dignity, Respect and Consent

The University is committed to promoting a positive environment where everyone is treated with dignity and respect, where work and study is free from bullying, or any form of harassment. Everyone within the University community has a responsibility to behave in a respectful way by respecting the dignity of others and participate in creating a positive culture for work and study.

Bullying and harassment (including sexual and racial harassment) are not tolerated in Trinity.

We are committed to the development of a culture where disclosure/reporting of any instance of bullying or harassment is encouraged. The University has a duty to act if it becomes aware of bullying and harassment without a complaint being made (such as through anonymous reporting below).

If you are experiencing bullying or harassment, or if you are the subject of a complaint of bullying / harassment, your first point of contact is Dignity, Respect & Consent Service, who have staff trained to deal with such matters as a confidential service. You can opt to make a disclosure or to make a complaint. Making a disclosure does not constitute raising a complaint, however you may decide to submit a complaint after seeking and receiving advice from the DR&C Service.

Visit **Dignity, Respect & Consent (DR&C) Service**: https://www.tcd.ie/hr/dignity-and-respect/



Students: Information for students about making a disclosure, making a complaint, receiving a complaint, training and support services are at: https://www.tcd.ie/hr/dignity-and-respect/students/



Speak Out provides the opportunity for you to make the University aware of incidents that you have either experienced or witnessed by reporting them **anonymously**. https://www.tcd.ie/hr/dignity-and-respect/speak-out/



Policies: Both the Dignity and Respect Policy and the Sexual Misconduct Policy are available from: https://www.tcd.ie/hr/dignity-and-respect/policies/

If you are unsure if you want to disclose something at a College level, or if you would prefer your matter to be dealt with locally in the School, you can disclose this **in confidence** to a member of Physics staff.

The main points of contact are:

- The School's Physics Disclosure Officer (PDO) - Dr Niamh McGoldrick (she/her), niamh.mcgoldrick@tcd.ie
- The School Director of Equality, Diversity & Inclusion – Prof. Lewys Jones (he/him), lewys.jones@tcd.ie, or to physics.inclusion@tcd.ie

Follow-up meetings can be arranged in person or online with either the PDO or Director of EDI as needed.

Emergency Contacts

On-campus Emergencies	College Emergency Telephone Number: +353 1 896 1999 On-Campus Security can be contacted in case of emergency on campus.
Off-campus Emergencies	An Garda Siochana (national Police Service of the Republic of Ireland) Call 999 or 112

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.

It is recommended that all students save at least one emergency contact in their phone under ICE (In Case of Emergency).

It is also recommended that students download the SafeZone app to access alerts for closures in inclement weather, etc.

School of Physics 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. Victor Usov	3530 (01-896 3530)
Laser Safety	Mr. Chris Smith	3649 (01-896 3649)
Electrical safety	Mr. Joe McCauley	2218 (01-896 2218)
First Aid	Campus Security Mr. James McLoughlin	1999(01-896 1999) 2714 (01-896 2714)

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's mission is to empower students with disabilities to achieve their potential and, in collaboration with students, engage the University community in creating an inclusive transformational environment and provide a platform for innovation and inclusion.

Service delivery within the Disability Service utilises a multi-disciplinary approach and is comprised of an experienced team of individuals who work to support the disabled student. The team includes Disability Officers who are Psychologists, Occupational Therapists, and an Assistive Technologist, all of whom seek to offer quality support based on individual need, as identified using a highly developed disability needs assessment process.

Disability Service Mission: To create an accessible, transformational, educational environment in an interdependent University community and provide a platform for innovation and inclusion.
Disability Service Vision: Engage the wider University community in empowering students with disabilities.
Disability Service Values: Inclusive, Advocating, Collaborative, Inquisitive, Pioneering, Positive disruptors, Dynamic.

The Disability Service has two principal functions, firstly, to provide supports to Trinity's disabled community (which comprises of students and staff, and indirectly; visitors) and to recommend policy and procedural changes as required. Secondly, the Disability Service ensures that Trinity is compliant with the Disability Act 2005 and other relevant legislation and codes of practice.

Student Disability Supports operate an appointment system to ensure that student queries and assessment interviews are handled in an efficient, effective, and confidential manner. Drop-in appointments can be made via the Disability Service Website.

The ethos of the Disability Service is to move from a transactional model of provision, where students are passive recipients of supports, to a transformational model of resource usage, where students take an active part in planning their educational journey. Trinity Disability Service is committed to coproduction of all activities with the student body. This is done through collaborative partnership with the TCD Ability co_op. The Trinity Ability co_op is a collaborative initiative between students, staff, and other stakeholders. The co_op provides opportunities for members to work together towards inclusion in Trinity. For more information or to find out how to join visit the Ability co_op webpage.

The Disability Service has a range of supports to ensure that students with disabilities have full access to the same facilities for study and recreation as their peers. The enabling disability supports provided by the Disability Service include:

- Exam Accommodations
- Library Supports
- Specialist Disability Supports:
    - Autism Spectrum Support
    - Neurodiversity Support
    - Applications for Rooms on Campus
    - Assistive Technology
    - Communicating with your School
    - Educational Support Work
    - Erasmus Disability Support Programme
    - Professional Placement Planning
    - Respite Space
    - Occupational Therapist Support
    - Personal Emergency Evacuation Plan (PEEP)
    - Planning your Career
    - Student Lockers
    - Irish Sign Language Support
    - Dyslexia Consultation

After applying online, students will be invited to meet with a member of the Disability Service team (Disability Officer/Occupational Therapist) on a one-to-one basis to discuss and agree the enabling Disability Supports put in place to meet their needs

Contact Information

- Web: tcd.ie/disability
- Email: askds@tcd.ie
- Phone: 01 896 3111
- Text: 087 113 3185



Have a question? Email askds@tcd.ie Phone 01 896 3111 Mobile 087 113 3185
DS Solutions Drop-in. Monday to Friday, 11am to 3pm (Term Time). Scan the QR code to book your Drop-in appointment.

College Health Service

The College Health Service is in Printing House Square and is open every weekday and provides inexpensive primary health and psychiatric care, by appointment. It is open Monday to Friday from 9.00 am to 5.00 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. Visit: https://www.tcd.ie/Careers/

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 for JS students in College in Semester 2 and includes information on applying for work experience and internships and postgraduate study. For JS students in the School of Physics, specific lectures on careers related to this take place in Semester 1 as part of JS students' practical modules. Further in the School of Physics, in Semester 2 networking events involving returning School of Physics graduates may occur.

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 Semester 1 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**.**

MyCareer

An online service that you can use to:

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

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

Careers Advisory Service

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

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

MyCareer: mycareerconnect.tcd.ie

TCD.Careers.Service

TCDCareers

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

@TCDCareers

tinyurl.com/LinkedIn-TCD-Connecting

Opening Hours

During term: 9.00am – 1.00pm and 2.00pm - 5.00pm, Monday - Friday

Out of Term: 9.00am - 1.00pm and 2.00pm - 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.

Theoretical Physics Student Association (TPSA)

The Theoretical Physics Student Association (TPSA) was created for the benefit of students from both physics and maths backgrounds. The TPSA aspire to create a sustainable environment to encourage collaboration between students, develop their academic skill set, improve their internship and career prospects, and overall work towards improving the ecosystem of physics and maths in Ireland.

Among the activities listed by the TPSA are:

- Student seminars every week for students of all years to work through problems and gain valuable insight into the field from older students.

- Talks from high level researchers and senior students about exciting research topics and how to make the most of your time as an undergraduate.
- A student run lecture series for students from all years.
- Training students to represent TCD in the International Theoretical Physics Olympiad.

The TPSA provide numerous opportunities for students to get involved, and it hopes that the benefit of what it does will be felt inside and outside of TCD in years to come.

More information about the TPSA can be found on the website: https://tpsa-ireland.github.io

Index of Modules

The School reserves the right to amend the list of available modules and to withdraw and add modules. Timetabling may restrict the mailability of modules to individual students.

PYU11T10 Physics for Theoretical Physics

Semester 1 – lectures, practical laboratory, online assignments & small group tutorials – 10 credits
(E. Keane, L. Matrà, K. Rode, C. Patterson, M. Fazeli Jadidi, D. O'Regan)

Introduction to Physics – 1 lecture
Introduction to the Physics Laboratory – 1 lecture
Special Relativity – 15 lectures + 3 tutorials
Waves and Optics I – 20 lectures
Tools for Physics (including Statistics) – 14 lectures

Learning Outcomes

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

- Express in mathematical language the motion of a body under the action of forces.
- Describe wave motion and relate it to basic phenomena in light and sound.
- Demonstrate understanding and use of physics-based problem-solving strategies
- Understand sources of errors in measurements and calculate their propagation.
- Prepare a brief report, which includes an error analysis, of a simple physical experiment.

Syllabus

Introduction to Physics – 1 lecture
An introduction to the School of Physics and the JF Physics course.

Special Relativity – 10 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 – 18-20 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.

Tool for Physics (including Statistics) – 14 lectures
Units, orders of magnitude, and dimensional analysis. Essential maths tools for physics.
Physical interpretation of differentiation and integration, and differential equations in physics.
Model construction, derivations, and problem solving based on physical principles.
Methods for solving equations and interpreting and explaining their results. Methods for approximating equations. Models for physical systems such as pendulum, spring, and capacitor.
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

Assessment	Weighting
Examination	60%
Laboratory Practical work	30%
Online assignments	10%

Note: There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement.

There is a maximum mark or cap of 60% on any reassessed component in this module if reassessment is required. The final module mark is calculated based on the reassessed component mark and any already achieved marks for components that did not need to be reassessed, according to the published weightings of these components.

Re-assessment capping does not apply to deferred 1st attempts at assessment.

These apply to all students in this module.

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PYU11T20 Physics for Theoretical Physics

Semester 2 – lectures, practical laboratory, online assignments & small group tutorials – 10 credits
(A. Lunghi, L. Jones, T. Pearce)

Electricity and Magnetism I – 20 lectures
Materials Physics – 18 lectures
Gravitation and Astrophysics – 14 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
- Describe elementary crystal structures and the response of materials to external forces
- Describe how the laws of thermodynamics react to properties of matter
- Develop the ideas of Newton's Law of Gravitation, and the motion of planets and satellites.
- Describe the main properties of planets, exoplanets, the Sun, and stars.

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.

Materials Physics – 16 lectures
Inter and intra-molecular forces, potential energy curves, translational, rotational and vibrational degrees of freedom, heat capacity, thermal expansion and thermal conductivity. Stress, strain, shear, elastic and plastic deformations of solids, bulk and elastic moduli. 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, surface tension. Conductive, convective and radiative transport of heat. Stefan-Boltzmann law.

Gravitation and Astrophysics – 14 lectures
Basic Astrophysical concepts: scale of the universe, our movement through space, celestial sphere and constellations. Motion of the planets: Newton's law of gravitation, gravitational potential energy, motion of satellites, Kepler's laws and the motion of planets, apparent weight and the earth's rotation, escape velocity. Our solar system - the planets: physical properties, composition, terrestrial planets, gas giants. Exoplanets and life in the Universe: planet formation, exoplanets detection and statistics, life in the universe. Stars: the electromagnetic spectrum, physical properties of the Sun and stars, Blackbody radiation, Wien's law, Stefan-Boltzmann law, introduction to the Hertzsprung-Russell Diagram. Binary stars: Doppler effect in astronomy, stellar masses, mass-luminosity-radius relationships. Telescopes: light-collecting power, angular resolution, telescope designs, types of observations.

Assessment	Weighting
Examination	60%
Laboratory Practical work	30%
Online assignments	10%

Note: There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement.

There is a maximum mark or cap of 60% on any reassessed component in this module if reassessment is required. The final module mark is calculated based on the reassessed component mark and any already achieved marks for components that did not need to be reassessed, according to the published weightings of these components.

Re-assessment capping does not apply to deferred 1st attempts at assessment.

These apply to all students in this module.

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PYU22T10 Physics for Theoretical Physics

Semester 1 – lectures, practical laboratory, project, online assignments and tutorials – 10 credits
(E. Keane, M. Hegner, G. Cross, P. Eastham)

This module combines elements of classical physics, as follows:

Observing The Universe – 14 lectures
Oscillations – 12 lectures + 3 tutorials
Thermodynamics – 14 lectures + 3 tutorials
Quantum Physics – 12 lectures + 3 tutorials

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

- Solve basic problems in relation to harmonic oscillators
- Describe elementary crystal structures and the response of materials to external forces
- Describe how the laws of thermodynamics react to properties of matter
- Explain a broad variety of astrophysical phenomena with simple physics
- Describe how physics of matter and radiation is underpinned by quantum physics.
- Describe the relationships between waves and particles and between observations and probabilities in quantum mechanics.
- Solve the one-dimensional Schrodinger equation for an infinite square well and interpret the results using the principles of quantum mechanics.
- Employ web-based research techniques in a small group project and present the results in the form of a poster
- Either prepare an extensive report detailing methodology, data gathering and interpretation of a physical experiment and obtain, pre-process, display and analyse experimental data using software packages such as Origin or analyse, modify and run Python language programs to perform computer experiments

Syllabus

Observing the Universe: - 12 lectures
Continuous radiation of stars: flux, luminosity, magnitudes, colours. Spectral lines in stars: spectral classification, origin of spectral lines, the Hertzsprung-Russell diagram. 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. Close binary evolution: mass transfer, supernova Type Ia, gravitational waves. Interstellar medium. Star formation: gravitational collapse, initial mass function. 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.

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. Examples of experimental measurements using MEMS resonators. Waves. Nonlinear behaviour. Anharmonic behaviour.

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.

Quantum Physics: - 12 lectures
Waves and complex numbers in quantum mechanics. Wave-particle duality. Wavefunctions as probability amplitudes and wavefunction collapse. The one-dimensional Schrodinger equation. Operators, eigenfunctions, and observables. Particle in an infinite potential well. The uncertainty principle. Particle in a 3D box. Quantum numbers of the hydrogen atom.

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

Note: There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement. A mark of less than 30% in either of these Examination or Laboratory components leads to a Qualified Fail, and requires reassessment examination or a repeat of the year.

There is a maximum mark or cap of 60% on any reassessed component in this module if reassessment is required. The final module mark is calculated based on the reassessed component mark and any already achieved marks for components that did not need to be reassessed, according to the published weightings of these components.

Re-assessment capping does not apply to deferred 1st attempts at assessment.

These apply to all students in this module.

For more details please see the section in the School of Physics Undergraduate Handbook on “Progression regulations applying to Physics modules and accredited Physics programmes” available in full at: https://www.tcd.ie/physics/study/current/undergraduate/handbook/ or see a summary at: https://www.tcd.ie/physics/study/current/undergraduate/progression.

PYU22T20 Physics for Theoretical Physics

Semester 2 – lectures, practical laboratory, online assignments and tutorials – 10 credits
(S. Hutzler, M. Stamenova, HZ Zhang, D. McCloskey)

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

Chaos and Complexity – 12 lectures + 3 tutorials
Nuclear and Particle Physics – 14 lectures + 3 tutorials
Electricity & Magnetism II – 14 lectures + 3 tutorials
Waves and Optics II – 14 lectures + tutorials

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

- Describe how modern physics is underpinned by nuclear and particle physics; waves and optics
- Express relativistic effects as observed in different inertial reference frames
- Relate the concept of oscillations to optical properties of matter and AC circuits
- Prepare calculations and present in small groups
- Analyse, modify and run Python language programs to perform computer experiments
- Obtain, pre-process, display and analyse (fit to analytical models) actual experimental data using software packages such as Origin

Syllabus

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

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

Waves & 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%
Online Assignments and Tutorials	10%

Note: There is a minimum mark requirement of 30% separately in the Examination component and the Laboratory component, in order for a Pass or Qualified Pass mark in the module to be granted. Other components making up fewer marks are not included in this requirement. A mark of less than 30% in either of these Examination or Laboratory components leads to a Qualified Fail, and requires reassessment examination or a repeat of the year.

There is a maximum mark or cap of 60% on any reassessed component in this module if reassessment is required. The final module mark is calculated based on the reassessed component mark and any already achieved marks for components that did not need to be reassessed, according to the published weightings of these components.

Re-assessment capping does not apply to deferred 1st attempts at assessment.

These apply to all students in this module.

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PYU33A03 Stellar and Galactic Structure

Semester 1 – 30 lectures/tutorials – 5 credits (K. Maguire, E. Keane)

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

Semester 2 – 5 credits (P. Gallagher, L. Matrà)

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 Radiative Transfer

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 Radiative Transfer 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	80%
Continuous Assessment in Astrophysical Radiative Transfer	10%
Continuous Assessment in Astrophysical Instrumentation	10%

PYU33AP3 Practical in Physics and Astrophysics

Semester 1 and Semester 2 – 10 credits (N. Gibson, K. Maguire, J. Vos, L. Bradley)

Part I: Computational Laboratory – 12 computational laboratory sessions
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:
· Understand and develop Python code at an advanced level
· Employ computer-based data analysis of multi-dimensional datasets
· Use advanced statistical inference tools to extract information from astrophysical datasets
· Prepare an extended analytical report on an experiment
· Apply learned skills to tackle unseen computational astrophysics problems
· Write a précis of a research seminar
· Make a scientific presentation to an audience
· Create a personal CV

Syllabus Part I: Computational Laboratory – 12 experimental laboratory sessions (of 6 hours duration). This module introduces computational Astrophysics to students using Python. The student will develop computational skills that can be further applied to theoretical, numerical and observational Astrophysical studies. The 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. Multiple sessions are dedicated to introducing the use of python in astrophysics through a series of worksheets that students complete at their own pace, and following this the students will use these skills to complete astrophysics experiments. At the end of the module, the student will have learned: python commands and modules; how to create, modify and operate on large multi-dimensional arrays; to create plots and images; to perform advanced model fitting; to create numerical models of diverse astrophysical phenomena; to create their own procedures, functions, and classes; to read and save data in common formats; to control the flow of program execution. 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 3 submitted reports. Experiments are subject to change but may include working with big datasets in supernova cosmology, fitting supernova light curves/galaxy spectra, modelling radial velocities of stars and transit light curves used for discovery and classification of exoplanet systems.

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 – Computational Lab Practical Work	80%
Continuous Assessment – Careers Workshop and Communications Skills	20%

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

Semester 2 – 10 practical laboratories of 4 hours duration – 5 credits (L. Matrà, K. Maguire, M. Fazeli Jadidi)

Learning Outcomes

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

- Operate advanced apparatus from manual instructions
- Maintain a laboratory notebook record
- Employ computer-based data analysis
- Apply appropriate error analysis
- Prepare an extended report on an experiment

Syllabus

Practical Laboratory – 10 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.

Assessment	**Weighting**
Continuous Assessment	100%

PYU33AP5 Practical in Physics and Astrophysics

Semester 1 – 5 credits (N. Gibson, K. Maguire, J. Vos)
* For students on Study Abroad programmes in Semester 2 only

Part I: Practical /Computational Laboratory – 6 experimental laboratory sessions (of 6 hours duration) or equivalent self-directed virtual laboratory experiments.

Learning Outcomes
On successful completion of this module, students should be able to:
· Understand and develop Python code at an advanced level
· Employ computer-based data analysis of multi-dimensional datasets
· Use advanced statistical inference tools to extract information from astrophysical datasets
· Prepare an extended analytical report on an experiment
· Apply learned skills to tackle unseen computational astrophysics problems

Syllabus Part I: Practical/Computational Laboratory – 6 experimental laboratory sessions (of 6 hours duration) or equivalent self-directed virtual laboratory experiments. This module introduces lab Physics and/or computational Astrophysics to students using Python. The student will develop laboratory/computational skills that can be further applied to theoretical, numerical and observational Physics/Astrophysics studies. The module will further equip students to carry out their final year research project in Year 4 of the degree. Experiments are subject to change. Advanced lab experiments range 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. Specificy astrophysics projects typically include working with big datasets in supernova cosmology, fitting supernova light curves/galaxy spectra, modelling radial velocities of stars and transit light curves used for discovery and classification of exoplanet systems.

Assessment	**Weighting**
Continuous Assessment – Computational Lab Practical Work	100%

PYU33AP6 Practical in Physics and Astrophysics

Semester 2 – 5 credits (N.Gibson, K. Maguire, M. Fazeli Jadidi)
* For students on Study Abroad programmes in Semester 1 only

Part I: Practical Laboratory – 6 experimental computational laboratory sessions (of 6 hours duration) or equivalent some of which may be self-directed virtual computational laboratory exercises.

Learning Outcomes
On successful completion of this module, students should be able to:
· Understand and develop Python code at an advanced level
· Employ computer-based data analysis of multi-dimensional datasets
· Use advanced statistical inference tools to extract information from astrophysical datasets
· Prepare an extended analytical report on an experiment
· Apply learned skills to tackle unseen computational astrophysics problems

Syllabus Part I: Computational Laboratory – 6 experimental laboratory sessions (of 6 hours duration) or equivalent self-directed virtual laboratory experiments. This module introduces computational Astrophysics to students using Python. The student will develop computational skills that can be further applied to theoretical, numerical and observational Astrophysical studies. The 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. Multiple sessions are dedicated to introducing the use of python in astrophysics through a series of worksheets that students complete at their own pace, and following this the students will use these skills to complete astrophysics experiments. At the end of the module, the student will have learned: python commands and modules; how to create, modify and operate on large multi-dimensional arrays; to create plots and images; to perform advanced model fitting; to create numerical models of diverse astrophysical phenomena; to create their own procedures, functions, and classes; to read and save data in common formats; to control the flow of program execution. 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 3 submitted reports. Experiments are subject to change, but typically include working with big datasets in supernova cosmology, fitting supernova light curves/galaxy spectra, modelling radial velocities of stars and transit light curves used for discovery and classification of exoplanet systems.

Assessment	**Weighting**
Continuous Assessment – Computational Lab Practical Work	100%

PYU33C01 – Computer Simulation I

Semester 1 – 30 lectures/tutorials – 5 credits (S. Hutzler, M. Stamenova)

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
- 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

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**
Examination in Numerical Methods	25%
Continuous Assessment in Numerical Methods	25%
Continuous Assessment in Computational Methods	50%

PYU33NP3 Practical in Nanoscience

Semester 1 and Semester 2 – 10 credits (L. Jones, P. Stamenov, S. Dooley, L. Bradley)

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 nanoscience 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 Communications Skills	20%

PYU33P01 Quantum Mechanics I

Semester 1 – 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

Semester 1 – 30 Lectures – 5 credits (D. O'Regan, L. Bradley)

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	100%

PYU33P03 Condensed Matter I

Semester 1 – 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 I

Semester 2 – 30 lectures/tutorials – 5 credits (D. O'Regan, P. Christie)

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	100%

PYU33P07 Experimental Techniques

Semester 2 – 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

Semester 2 – 30 lectures/tutorials – 5 credits (G. Cross, A. Lunghi)

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.

The Atomic Physics part of this module covers how the principles of quantum mechanics apply to atomic systems. The students will learn how to solve the Schroedinger equation for the Hydrogen atom and how its solutions can be used to interpret spectroscopic experiments, including optical absorption and magnetic resonance. Advanced topics will cover how relativistic and many-electron effects shape the electronic structure of atoms.

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
- Apply the laws of quantum mechanics to the hydrogen atom
- Interpret the hydrogen atom wave-functions
- Describe the fine structure and magnetic field effects in the hydrogen atom
- Correctly describe and interpret many-electron wave-functions
- Use perturbation theory to describe inter-electronic interactions in multi-electron atoms

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 Physics

History of atomic physics, review of Dirac notation, hydrogen atom Hamiltonian, solution of the Schroedinger equation for the hydrogen atom, description of atomic orbitals, angular momentum, Zeeman effect, perturbation theory, spin-orbit coupling, addition of angular momenta, many-electron atoms and anti-symmetry, Helium atom, spin-adapted wave-functions, Alkali atoms, spectral symbols, Hund's rules.

Assessment	**Weighting**
Examination in Atomic Physics	50%
Continuous Assessment in Statistical Thermodynamics	50%

PYU33PP3 Practical in Physics

Semester 1 and Semester 2 – 10 credits (G. Cross, C. McGuinness, M. Fazeli Jadidi, K. Zhussupbekov, L. Bradley)

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 Communications Skills	20%

PYU33PP4 Practical in Physics

Semester 2 – 5 credits (G. Cross, C. McGuinness, K. Zhussupbekov)

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%

PYU33PP5 Practical in Physics

Semester 1 – 5 credits (G. Cross, C. McGuinness, M. Fazeli Jadidi, K. Zhussupbekov)

* For students on Study Abroad programmes in Semester 2 or for Visiting students present in Semester 1 only

Part I: Practical Laboratory – 7 experimental laboratory sessions (of 6 hours duration).
Part II: Communication Skills – a selection of available 10 lectures/workshops/exercises
Part III: School Seminars – 4 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

Syllabus

Part I: Practical Laboratory – 7 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.

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

PYU33PP6 Practical in Physics

Semester 2 – 5 credits (G. Cross, C. McGuinness, M. Fazeli Jadidi, K. Zhussupbekov)

* For students on Study Abroad programmes in Semester 1 only or for Visiting students present in Semester 2 only, if requiring 10 credits of laboratories i.e. in addition to PYU33PP4.

Part I: Practical Laboratory – 7 experimental laboratory sessions (of 6 hours duration) or equivalent self-directed virtual laboratory experiments.

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

Syllabus

Part I: Practical Laboratory – 7 experimental laboratory sessions (of 6 hours duration) or equivalent self-directed virtual laboratory experiments. 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.

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

PYU33T15 Atomic Physics and Quantum Optics

Semester 2 – 30 lectures/tutorials – 5 credits (F. Binder, A. Lunghi)

Overview

This module provides an introduction to modern quantum optics with a focus on quantum states of light. Starting from quantisation of the electromagnetic field students will learn about the most important descriptions of quantum states of light and their phase-space representations. The emphasis is on physical intuition, statistical properties of light, and characteristics of non-classicality. The module includes an introduction to basic atom-light interaction.

The module also covers how the principles of quantum mechanics apply to atomic systems. The students will learn how to solve the Schroedinger equation for the Hydrogen atom and how its solutions can be used to interpret spectroscopic experiments, including optical absorption and magnetic resonance. Advanced topics will cover how relativistic and many-electron effects shape the electronic structure of atoms.

Part I: Quantum and Atom Optics
Part II: Atomic Physics

Learning Outcomes

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

- Quantise the electromagnetic field and describe photon number states.
- Define and analyse coherent and and squeezed states of light and describe them in phase space.
- Interpret the statistical properties of quantum light using photon statistics.
- Use quasi-probability distributions to analyse quantum states of light and identify non-classical states.
- Outline the principles of basic atom-light interaction.
- Apply the laws of quantum mechanics to the hydrogen atom
- Interpret the hydrogen atom wave-functions
- Describe the fine structure and magnetic field effects in the hydrogen atom
- Correctly describe and interpret many-electron wave-functions
- Use perturbation theory to describe inter-electronic interactions in multi-electron atoms

Syllabus Part I: Quantum Optics

Field quantisation and number states, coherent states and displacement, squeezed and Gaussian states, phase-space representations, quasiprobability distributions, nonclassical light, the basics of atom-light interactions

Part II: Atomic Physics

History of atomic physics, review of Dirac notation, hydrogen atom Hamiltonian, solution of the Schroedinger equation for the hydrogen atom, description of atomic orbitals, angular momentum, Zeeman effect, perturbation theory, spin-orbit coupling, addition of angular momenta, many-electron atoms and anti-symmetry, Helium atom, spin-adapted wave-functions, Alkali atoms, spectral symbols, Hund's rules.

Assessment	**Weighting**
Examination	100%

PYU33TP1 Practical in Theoretical Physics

Semester 1, Semester 2 – 10 credits (N. Gibson, P. Eastham, J.Goold, M. Fazeli Jadidi, L. Bradley)

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 – 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 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 – 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.

Part III: School Seminars – 8 Seminars

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

PYU33TP5 Practical in Theoretical Physics

Semester 1 – 5 credits (N. Gibson, P. Eastham, J. Goold, M. Fazili Jadidi)
* For students on Study Abroad programmes in Semester 2 only

Part I: Practical laboratory – 4 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.

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

Syllabus

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

Assessment	**Weighting**
Assessment – Laboratory practical work	100%

PYU33TP6 Practical in Theoretical Physics

Semester 2 – 5 credits (N. Gibson, P. Eastham, J. Goold, M. Fazeli Jadidi)
* For students on Study Abroad programmes in Semester 1 only

Part I: Practical laboratory – 6 experimental laboratory sessions (of 4 hours duration).
Part II: Communication Skills – 10 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

Syllabus

Part I: Practical laboratory – 6 experimental laboratory sessions (of 4 hours duration).

Assessment	**Weighting**
Assessment – Laboratory practical work	100%

PYU44A02 Advanced Topics in Astrophysics

Semester 1, Semester 2 – 48 lectures/tutorials – 10 credits – (L. Matrà, N. Gibson, E. Keane, K. Maguire)

Learning Outcomes

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

- Describe the observed properties of the solar system and relate them to formation
- Explain the origin of a circumstellar disk from star formation, and the angular momentum problem
- Explain the connection between young stellar object observations and their evolution
- Describe the key physical drivers of the vertical+radial structure and evolution of gas-rich protoplanetary disks, the birth places of planets
- Describe the main physical processes in the growth of terrestrial and giant planets all the way from small dust grains within a protoplanetary disk
- Carry out analytical calculations to estimate physical parameters relevant to planet formation and its disk environment, connecting observations to covered theory.
- Derive the equations responsible for the stability of planetary atmospheres
- Explain the main exoplanet detection techniques and the physical information we derive from these observations
- Understand the key methods for observing exoplanet atmospheres and the connection to searching for life in the Universe.
- Achieve the learning outcomes of the Cosmology and High Energy Astrophysics module PYU44A03.

Syllabus

Part I: Exoplanets and Planet Formation
This course starts with an overview of the Solar System, before focussing on planet formation within proto-planetary disks as a natural outcome of the star formation process. It also introduces the main methods to discover exoplanet systems, discusses their demographics and how this connects to planet formation. We also cover atmospheric physics, how to observe exoplanet atmospheres, and the connection to the hunt for life elsewhere in the Universe.

Part II: Cosmology and High Energy Astrophysics
The syllabus for this part of the course is given in the following entry for Cosmology and High Energy Astrophysics PYU44A03.

Assessment	**Weighting**
Examination in Exoplanets and Planet Formation	50%
Examination in Cosmology and High Energy Astrophysics	40%
Continuous Assessment in Cosmology and High Energy Astrophysics	10%

PYU44A03 Cosmology and High Energy Astrophysics

Semester 2 – 24 lectures/tutorials – 5 credits (E. Keane, K. Maguire)

Learning Outcomes

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

- Be able to explain the basic concepts of the subject of physical cosmology 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.
- Understand and apply the key physical mechanisms responsible for high-energy radiation in astrophysical environments, including both thermal and non-thermal processes.
- Explain how relativistic particles are accelerated in astrophysical shocks and magnetic fields, and how these processes give rise to cosmic rays and high-energy emission.
- Analyse the physics of accretion onto compact objects, including the role of angular momentum transport and the resulting observational signatures.
- Relate fundamental physical processes to observed high-energy phenomena across astrophysical systems, from compact objects and jets to galaxies and transient events.

Syllabus

Part I: Cosmology

Starting with basic cosmological observations and the basic foundational cosmological postulates, this course derives far-reaching results using information from first Newtonian principles and then from a GR-consistent approach. The implications of the most recent results concerning Dark Matter and Dark Energy are also discussed, together with possible future observational and research directions. On completion of the course, students will have an understanding of the basic properties of the Universe, how they have been derived and tested from observational and theoretical approaches, an appreciation for the youth of the field, recent and likely future developments.

Part II: High Energy Astrophysics

This course introduces the physics of high-energy astrophysical processes, beginning with the fundamental radiation mechanisms that govern emission from hot and relativistic plasmas. It then develops the theory of particle acceleration and cosmic rays, alongside methods for their detection, before moving on to the physics of accretion onto compact objects and the formation of accretion disks. These ideas are extended to compact astrophysical systems such as neutron stars and relativistic jets, where strong gravity and magnetic fields shape observed phenomena. The course concludes with applications to active galactic nuclei and high-energy transient events, highlighting how the underlying physical principles manifest across a wide range of astrophysical environments.

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

PYU44C01 Computer Simulation II

Semester 2 – 24 lectures/tutorials – 5 credits (C. Patterson)

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	80%
Continuous Assessment	20%

PYU44N02 Nanoscience, Complex Fluids & Polymers

Semester 1, Semester 2 – 48 lectures/tutorials – 10 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 Polymers	25%
Examination in Nanoscience & Complex fluids	50%
Continuous Assessment in Nanoscience	25%

PYU44NP2 Nanoscience Research Project

Semester 1, Semester2 – 20 credits

This module comprises a 9-week full-time research project conducted in either the School of Physics, the School of Chemistry, 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

Semester 1– 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%

PYU44P05 Electromagnetic Interactions II

Semester 2 – 24 lectures/tutorials – 5 credits (C. Patterson, HZ Zhang)

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	90%
Continuous Assessment in Electromagnetic Theory	10%

PYU44P06 Modern Optics

Semester 2 – 24 lectures – 5 credits (L. Bradley, D. McCloskey)

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%

PYU44P11 Advanced Quantum Mechanics, Nuclear Structure and High Energy Physics

Semester 1, Semester 2 – 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 Structure and High Energy Physics

Semester 2 – 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

Semester 2 – 24 lectures/tutorials – 5 credits (P. Stamenov, H. Zhang)

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	100%

PYU44P16 Quantum Plasmonics and Metamaterials

Semester 2 – 24 lectures/tutorials – 5 credits (O. Hess)

Learning Outcomes

On successful completion of this module, students should:

(1) Have an understanding of quantum plasmonics:

- Fundamentals of photonics of metallic and dielectric nanostructures up to extreme nanoscales
- Understand localized plasmons and surface plasmon polaritons
- Be familiar with nanoplasmonic open cavities
- Appreciate the foundations and opportunities of quantum plasmonics
- Have an insight into the physics of quantum emitters in nanoplasmonics
- Have an overview of applications of nanoplasmonics in quantum sensing and for quantum photonics

(2) Have an insight into the physics of metamaterials:

- Metamaterials concept: function from structure
- Have an understanding of the optics of materials with near-zero and negative refractive index
- Know how to achieve a material with near-zero and negative refractive index
- Understand the function of perfect lenses, optical cloaking, superlenses
- Appreciate slow light and trapped rainbows
- Understand active metamaterials

Syllabus

Introduction

A. Fundamentals of Quantum Plasmonics:

- Surface Plasmons (plasma oscillations, ponderomotive force, screening, surface plasmon polaritons at plane interfaces, surface plasmon nano-optics)
- Nanoplasmonic Cavities (characteristic geometries, quasi-normal mode theory)
- Quantum Emitters in Nanoplasmonic Cavities (quantum emitters, weak and strong coupling, density matrix theory, plasmonic spatio-temporal dynamics)

B. Physics of Metamaterials:

- Near-zero and Negative Refractive Index Optics (permittivities, permeabilities, perfect lens, trapped rainbow, radiative rates, reversal of Doppler and Cerenkov effects)
- Materials for Negative and Near-Zero Index (negative permittivity, negative permeability, transmission line metamaterials)
- Hyperbolic and Chiral Metamaterials
- Active Metamaterials (gain-enhanced nanoplasmonic metamaterials, metamaterial EIT, thermal meta-emitters)

Assessment	**Weighting**
Examination	100%

PYU44P17 Energy Science

Semester 2 – 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

Semester 1, Semester 2 – 20 credits (Co-ordinator P. Eastham)

This module comprises a 9-week full-time research project in Physics or in 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

Semester 1 – 5 credits (Co-ordinators C. McGuinness and I. Shvets)

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

Semester 1 – 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%

PYU44T30 Electronic Transport in Nanostructures

Semester 2 – 24 lectures/tutorials – 5 credits (M. Ferreira)

Learning Outcomes

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

- Explain the physical origin of quantum transport phenomena in nanoscale materials, molecular systems, and low-dimensional solids, distinguishing quantum behaviour from classical transport.
- Describe the role of Green functions in quantum physics and explain how they connect electronic structure, scattering processes, density of states, and transport properties.
- Explain the electronic structure of low-dimensional materials using tight-binding and lattice Hamiltonians, including finite, semi-infinite, and periodic systems.
- Discuss the influence of impurities, defects, surfaces, interfaces, and contacts on the electronic and transport properties of nanoscale systems.

Syllabus

Planck distribution, shot noise, photon counting statistics, Poissonian, sub-Poissonian and super-
This module introduces the theoretical foundations and computational methods used to describe quantum transport in nanoscale materials and molecular structures. Emphasis is placed on the Green-function formalism as a unifying framework connecting electronic structure, scattering, quantum coherence, disorder, and transport phenomena. Applications include low-dimensional solids, molecular junctions, nanotubes, graphene-based systems, surfaces, interfaces, and nanoscale devices. Students will develop the ability to formulate and analyse transport problems using both analytical and semi-analytical approaches based on Green functions, tight-binding models, scattering theory, and modern transport formalisms. The module bridges fundamental quantum mechanics and contemporary nanoscale transport research.

Assessment	**Weighting**
Examination	70%
Continuous Assessment	30%

PYU44TP1 Research Project

Semester 1, Semester 2 – 20 credits (Co-ordinator in School of Physics –D O'Regan)

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%

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