Swansea University
Prifysgol Abertawe

FACULTY OF SCIENCE AND ENGINEERING

POSTGRADUATE STUDENT HANDBOOK

MPHYS (FHEQ LEVEL 7)

MPHYS THEORETICAL PHYSICS
DEGREE PROGRAMMES

SUBJECT SPECIFIC
PART TWO OF TWO
MODULE AND COURSE STRUCTURE
2022-23

DISCLAIMER

The Faculty of Science and Engineering has made all reasonable efforts to ensure that the information contained within this publication is accurate and up-to-date when published but can accept no responsibility for any errors or omissions.

The Faculty of Science and Engineering reserves the right to revise, alter or discontinue degree programmes or modules and to amend regulations and procedures at any time, but every effort will be made to notify interested parties.

It should be noted that not every module listed in this handbook may be available every year, and changes may be made to the details of the modules. You are advised to contact the Faculty of Science and Engineering directly if you require further information.

The 22-23 academic year begins on 19 September 2022

Full term dates can be found here

DATES OF 22-23 TERMS
19 September 2022 – 16 December 2022
9 January 2023 – 31 March 2023
24 April 2023 – 09 June 2023

SEMESTER 1
19 September 2022 – 27 January 2023
SEMESTER 2
30 January 2023 – 09 June 2023
SUMMER
12 June 2023 – 22 September 2023

IMPORTANT

Swansea University and the Faculty of Science of Engineering takes any form of **academic misconduct** very seriously. In order to maintain academic integrity and ensure that the quality of an Award from Swansea University is not diminished, it is important to ensure that all students are judged on their ability. No student should have an unfair advantage over another as a result of academic misconduct - whether this is in the form of **Plagiarism**, **Collusion** or **Commissioning**.

It is important that you are aware of the **guidelines** governing Academic Misconduct within the University/Faculty of Science and Engineering and the possible implications. The Faculty of Science and Engineering will not take intent into consideration and in relation to an allegation of academic misconduct - there can be no defence that the offence was committed unintentionally or accidentally.

Please ensure that you read the University webpages covering the topic – procedural guidance here and further information here. You should also read the Faculty Part One handbook fully, in particular the pages that concern Academic Misconduct/Academic Integrity. You should also refer to the Faculty of Science and Engineering proof-reading policy and this can be found on the Community HUB on Canvas, under Course Documents.

Welcome to the Faculty of Science and Engineering!

Whether you are a new or a returning student, we could not be happier to be on this journey with you.

This has been a challenging period for everyone. The COVID-19 pandemic has prompted a huge change in society as well as how we deliver our programmes at Swansea University and the way in which you study, research, learn and collaborate. We have been working hard to make sure you will have or continue to having an excellent experience with us.

We have further developed some exciting new approaches that I know you will enjoy, both on campus and online, and we cannot wait to share these with you.

At Swansea University and in the Faculty of Science & Engineering, we believe in working in partnership with students. We work hard to break down barriers and value the contribution of everyone. Our goal is an inclusive community where everyone is respected, and everyone's contributions are valued. Always feel free to talk to academic staff, administrators, and your fellow students - I'm sure you will find many friendly helping hands ready to assist you.

We all know this period of change will continue and we will need to adapt and innovate to continue to be supportive and successful. At Swansea we are committed to making sure our students are fully involved in and informed about our response to challenges.

In the meantime, learn, create, collaborate, and most of all – enjoy yourself!

Professor Johann (Hans) Sienz
Interim Pro-Vice Chancellor/Interim Executive Dean
Faculty of Science and Engineering

Faculty of Science and Engineering	
Interim Pro-Vice Chancellor/Interim Executive Dean	Professor Johann Sienz
Head of Operations	Mrs Ruth Bunting
Associate Dean – Student Learning and Experience (SLE)	Professor Paul Holland
School of Biosciences, Geography and Physics **Head of School: Siwan Davies**	
School Education Lead	Dr Laura Roberts
Head of Physics	Dr Daniel Thompson and Professor Prem Kumar
Physics Programme Director	Professor David Dunbar
Year Coordinators	Year 0 – Dr Warren Perkins Year 1 – Dr Timothy Burns Year 2 – Professor Ardalan Armin Year 3 – Professor Timothy Hollowood Year M – Dr Kevin O'Keeffe

STUDENT SUPPORT

The Faculty of Science and Engineering has two **Reception** areas - Engineering Central (Bay Campus) and Wallace 223c (Singleton Park Campus).

Standard Reception opening hours are Monday-Friday 9am-5pm.

The **Student Support Team** provides dedicated and professional support to all studentsin the Faculty of Science and Engineering. Should you require assistance, have any questions, be unsure what to do or are experiencing difficulties with your studies or in your personal life, our team can offer direct help and advice, plus signpost you to further sources of support within the University. There are lots of ways to get information and contact the team:

Email: studentsupport-scienceengineering@swansea.ac.uk (Monday–Friday, 9am–5pm)

Call: +44 (0) 1792 295514 and 01792 6062522 (Monday-Friday, 10am–12pm, 2–4pm).

Zoom: By appointment. Students can email, and if appropriate we will share a link to our Zoom calendar for students to select a date/time to meet.

The current student **webpages** also contain useful information and links to otherresources:

https://myuni.swansea.ac.uk/fse/coe-student-info/

READING LISTS

Reading lists for each module are available on the course Canvas page and are also accessible via http://ifindreading.swan.ac.uk/. We've removed reading lists from the 22-23 handbooks to ensure that you have access to the most up-to-date versions. Access to print material in the library may be limited due to CV-19; your reading lists will link to on-line material whenever possible. We do not expect you to purchase textbooks, unless it is a specified key text for the course.

THE DIFFERENCE BETWEEN COMPULSORY AND CORE MODULES

Compulsory modules must be **pursued** by a student.

Core modules must not only be **pursued**, but also **passed** before a student can proceed to the next level of study or qualify for an award. Failures in core modules must be redeemed.

Further information can be found under "Modular Terminology" on the following link - https://myuni.swansea.ac.uk/academic-life/academic-regulations/taught-guidance/essential-info-taught-students/your-programme-explained/

Year 4 (FHEQ Level 7) 2022/23
Theoretical Physics
MPhys Theoretical Physics[F340]

Total 125 Credits

Optional Modules

Choose a maximum of 60 credits

PH-M03	Quantum Field Theory	Prof DC Dunbar	TB1	10
PH-M04	Advanced Particle Physics	Prof A Armoni	TB1	10
PH-M08	Modern Laser Systems	Dr K O'Keeffe	TB2	10
PH-M10	Atomic and Quantum Optics III	Prof SJ Eriksson	TB1	10
PH-M28	Machine Learning for Physicists	Prof GAP Aarts	TB1	10
PH-M29	Quantum Gravity	Prof TJ Hollowood/Prof SP Kumar/Prof C Nunez/..	TB2	10
PH-M32	Quantum Information Processing	Prof GAP Aarts	TB2	10
PH-M35	Medical Imaging and Spectroscopy: From MRI to photonics	Dr SM Shermer	TB2	10

And

Choose exactly 60 credits

PH-M24	Research Project	Prof SP Kumar	TB1+2	60
PH-M24C	Prosiect Ymchwil	Dr CA Isaac	TB1+2	60

PH-M03 Quantum Field Theory

Credits: 10 Session: 2022/23 September-January

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof DC Dunbar

Format: 22 lectures, 3 feedback sessions

Delivery Method: Lectures and feedback sessions.

Module Aims: An introduction to quantum field theory.

Module Content: 1. Classical field theory, Lagrangians, Noether theorem.

2. Canonical quantization of scalar fields.

3. Fermions, quantization.

4. Gauge fields.

5. Interactions.

6. Perturbation theory, Feynman graphs.

7. Renormalization of QED at the one loop level, vacuum polarisation, Lamb shift.

Intended Learning Outcomes: Students will gain an understanding of quantum field theory and an introduction to how to calculate some physical processes.

Students will be able to perform calculations and solve problems based on the content of this module taking the form of analytical and/or numerical calculations without the use of text books or other sources.

Students will be able to demonstrate that they have mastered the content of the module by being able to define and summarize important terms and concepts, recall key formulae without the aid of text books or other sources.

Assessment: Examination 1 (70%)
Coursework 1 (30%)

Resit Assessment: Examination (Resit instrument) (100%)

Assessment Description: Examination (70%): 2 hour written exam.
Continuous Assessment (20%): 2 pieces of coursework
Engagement Exercises (10%): 3 exercises

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Not available to exchange students.

PH-M04 Advanced Particle Physics

Credits: 10 Session: 2022/23 September-January

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof A Armoni

Format: 22 lectures, 3 feedback sessions

Delivery Method: Lectures and feedback sessions.

Module Aims: The first part of course examines the Dirac equation in relativistic quantum mechanics and its use in the context of quantum field theory.

The second part of the course develops in some details the physics of two recent advances in particle physics (the discovery of neutrino oscillations and of the Higgs particle) and their importance in the context of the Standard Model of particle physics.

Module Content: A The Dirac Equation and its Consequences

0) Conventions
1) Lorentz Invariance
2) Relativistic Wave Equation
3) The Dirac Equation
4) Free particle solutions of the Dirac equation
5) Interpretation : Spin
6) Spinors and Lorentz transformations
7) Weyl and Majorana Spinors

B. Neutrino physics and neutrino oscillations.

C. The Standard Model as a Quantum Field Theory. Spontaneous Symmetry Breaking, Goldstone theorem and Higgs mechanism. The Higgs particle.

Intended Learning Outcomes: The students will understand how combining quantum mechanics and relativity leads to physics predictions.
Students will gain a deeper understanding of contemporary particle physics.
Students will be able to perform calculations and solve problems based on the content of this module taking the form of analytical and/or numerical calculations without the use of text books or other sources.
Students will gain an understanding of the importance of the interplay between experiment and theory in large scale experiments.

Assessment: Examination 1 (70%)
Coursework 1 (30%)

Resit Assessment: Examination (Resit instrument) (100%)

Assessment Description: Examination (70%): 2 hour written exam.
Continuous Assessment (20%): 2 pieces of coursework
Engagement Exercises (10%): 3 exercises

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Available to exchange students.

PH-M08 Modern Laser Systems

Credits: 10 Session: 2022/23 January-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Dr K O'Keeffe

Format: 22 lectures, 3 feedback sessions

Delivery Method: Lectures and feedback sessions.

Module Aims: The objective of this module is to develop a link between basic principles of laser physics and the practical realization of laser systems, which have revolutionised laser applications.

Module Content: Besides the fundamentals of selected laser systems, aspects of assessing specific laser parameters and characteristics will be discussed, as well as some key applications in atomic and molecular physics. The following topics will be addressed:

1. The basics of laser action: 3-level and 4-level systems; simple rate equations; laser cavities (including mode structure).
2. Continuous wave lasers: exemplified for semiconductor diode and Nd:YAG lasers - fundamental principles and practical realisation; operation; wavelength and intensity distributions; wavelength selection; selected applications.
3. Pulsed solid-state laser sources: exemplified for Nd:YAG and Ti:sapphire lasers - fundamental principles and practical realisation; wavelength, intensity and time distributions (including Q-switching); selected applications.
4. Ultra-short laser pulses: generating and characterising femto-second (fs) pulses; the use of fs-laser sources in atomic and molecular physics.

Intended Learning Outcomes: To develop an in depth understanding of the fundamental physics behind modern laser systems, as well as the tools and techniques used to optimize these devices.

To understand the operating principles, and real-world applications, of a wide range of laser systems.

To develop an understanding of how modern lasers can be used to probe atomic and molecular systems.

Students will be able to perform calculations and solve problems based on the content of this module taking the form of analytical and/or numerical calculations without the use of text books or other sources.

Students will be able to demonstrate that they have mastered the content of the module by being able to define and summarize important terms and concepts, recall key formulae without the aid of text books or other sources.

Assessment: Coursework 1 (30%)
Examination 1 (70%)

Resit Assessment: Examination (Resit instrument) (100%)

Assessment Description: 70% Written Exam - 2 hours
30% Coursework consisting of 3 assessed problem sheets

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Available to exchange students.

PH-M10 Atomic and Quantum Optics III

Credits: 10 Session: 2022/23 September-January

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof SJ Eriksson

Format: 22 lectures, 3 feedback sessions

Delivery Method: Lectures and feedback sessions.

Module Aims: This module deepens the student's understanding of atomic physics and quantum optics to a level which enables the student to participate under guidance in a research group involved in cutting edge research in the field.

Module Content: 1. Magnetic trapping: The principle of magnetic trapping, stable trapping geometries, examples of traps used in modern experiments
2. Bose-Einstein condensation: evaporative cooling and experimental realisation in dilute atomic vapours, basic properties
3. Ion trapping: Earnshaw's theorem, the Paul trap, the Penning trap, applications in quantum information processing and precision measurements
4. Classical models of light: the gaussian beam, quadrature amplitudes, modulation, coherence
5. Quantum models of light: Fock states, coherent states, quantum noise

Intended Learning Outcomes: Students will deepen their understanding of atomic physics and quantum optics.
Students will learn the basic physics behind recent discoveries in atomic physics and quantum optics.

Students will be able to perform calculations and solve problems based on the content of this module taking the form of analytical and/or numerical calculations without the use of text books or other sources.

Students will be able to demonstrate that they have mastered the content of the module by being able to define and summarize important terms and concepts, recall key formulae without the aid of text books or other sources.

Assessment: Examination 1 (70%)
Coursework 1 (30%)
Resit Assessment: Examination (Resit instrument) (100%)

Assessment Description: Examination (70%): 2 hour written exam.
Continuous Assessment (20%): 2 pieces of coursework
Engagement Exercises (10%): 3 exercises

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Available to exchange students.

PH-M24 Research Project

Credits: 60 Session: 2022/23 September-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof SP Kumar

Format: Project description (4 hours), updates on progress with project supervisor (16 hours).

Delivery Method: Individual sessions with project supervisor and self study.

Module Aims: Students will perform individual projects based on advanced Physics topics.

Module Content: This module will be based on a physics project that is aimed at reinforcing the problem solving abilities and the technical skills of the students.The project will take place either on TB2 or on TB3, according to the programme followed by the student, and will last for the whole corresponding term. Each project will have a supervisor and the student should liaise closely with the supervisor at all times. In addition to the written report, due by the end of the term, students will give a presentation and answer questions on their work. This session will be used to inform the assessment of the dissertation.

Intended Learning Outcomes: Students will gain experience in original research.

Assessment: Report (100%)
Resit Assessment: Coursework reassessment instrument (100%)

Assessment Description: The students will need to write a report on their project detailing the aims of the project and containing a literature review, description of the work performed and conclusion drawn from it. The length of the report is 20000 words.

Moderation approach to main assessment: Universal non-blind double marking

Assessment Feedback: The student is in constant contact with the project supervisor, who will give her/him feedback about the work performed.

Failure Redemption: Failure can be redeemed by liaising with the project supervisor to correct the aspects of the projects that have been judged substandard and resubmitting the amended dissertation (or a new dissertation, if the student failed to submit) by the appropriate date (either June or September) for the final assessment of the programme the student has been following.

Additional Notes: Not available to visiting and exchange students.

PH-M24C Prosiect Ymchwil

Credits: 60 Session: 2022/23 September-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Dr CA Isaac

Format: Disgrifiad o’r prosiect (4 awr), diweddariadau ar gynnydd gyda goruchwilwr prosiect (16 awr).

Delivery Method: Sesiynau unigol gyda goruchwyliwr prosiect ac astudio annibynnol.

Module Aims: Bydd myfyrwyr yn perfformio prosiectau unigol sy’n seiliedig ar destunau Ffiseg uwch.

Module Content: Bydd y modiwl hwn yn cael ei seilio ar brosiect ffiseg sydd wedi'i anelu at atgyfnerthu galluoedd datrys problemau a sgiliau technegol y myfyrwyr. Bydd y prosiect yn cael ei gynnal naill ai yn ystod CD2 neu CD3 yn ôl y rhaglen a ddilynir gan y myfyriwr, ac yn para am y cyfnod cyfatebol cyfan. Bydd pob prosiect yn cael goruchwyliwr a dylai'r myfyriwr gysylltu'n agos a'r goruchwyliwr ar bob adeg. Yn ychwanegol i'r adroddiad ysgrifenedig, sy'n ddyledus erbyn diwedd y tymor, bydd y myfyrwyr yn rhoi cyflwyniad ac yn ateb cwestiynau ar eu gwaith. Bydd y sesiwn yn cael ei ddefnyddio i hysbysu asesiad y traethawd hir.

Intended Learning Outcomes: Caiff myfyrwyr profiad o waith ymchwil gweiddiol.

Assessment: Coursework 1 (100%)
Resit Assessment: Coursework reassessment instrument (100%)

Assessment Description: Bydd angen i'r myfyrwyr i ysgrifennu adroddiad ar ei brosiect sy'n manylu ar amcanion y prosiect ac yn cynnwys adolygiad llenyddol, disgrifiad o'r gwaith a gyflawnir a'r casgliadau a dynnwyd ohono. Hyd yr adroddiad yw 20000 o eiriau.

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Mae¿r myfyriwr mewn cysylltiad cyson â¿r goruchwyliwr prosiect a fydd yn rhoi adborth am y gwaith a wnaed.

Failure Redemption: Gall methiant ei hadennill drwy gysylltu gyda'r goruchwyliwr prosiect i gywiro unrhyw agweddau o'r prosiect sydd wedi cael eu barnu'n is-safonol ac yna ail gyflwyno'r traethawd hir diwygiedig (neu draethawd hir newydd, os bod y myfyriwr wedi methu cyflwyno) erbyn y dyddiad priodol (naill ai mis Mehefin neu fis Medi) ar gyfer yr asesiad terfynol o'r rhaglen y mae'r myfyriwr wedi bod yn dilyn.

Additional Notes: Dim ar gael i fyfyrwyr sy'n ymweld nac rhai cyfnewidiol.

PH-M28 Machine Learning for Physicists

Credits: 10 Session: 2022/23 September-January

Pre-requisite Modules: PH-204; PH-353

Co-requisite Modules:

Lecturer(s): Prof GAP Aarts

Format: two 1 hr lecture per week

Delivery Method: In person lecturing

Module Aims: A module which gives an introduction to the concepts and practices of Machine Learning with a focus upon the aspects and applications relevant to Physics.

Module Content: 1) introduction to Machine Learning
2) optimisation techniques
3) linear regression
4) classification
5) unsupervised learning
6) feature selection
7) cross-validation
8) kernel methods
9) fully connected neural networks
10) convolutional neural networks

Intended Learning Outcomes:
An understanding of the basic concepts of Machine Learning

An in depth understanding of the algorithms used in Machine Learning

An understanding of how Machine Learning can be applied to Physics problems

Assessment: Other (100%)
Resit Assessment: Coursework reassessment instrument (100%)

Assessment Description: Assessment via coursework

Moderation approach to main assessment: Universal second marking as check or audit

Assessment Feedback: Canvas will be the primary method for returning feedback. Coursework will be submitted via canvas and marked. Students work will be annotated and returned after marking.

Failure Redemption: Resit coursework

Additional Notes: available to visiting and exchange students with suitable background in PYTHON coding.

PH-M29 Quantum Gravity

Credits: 10 Session: 2022/23 January-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof TJ Hollowood, Prof SP Kumar, Prof C Nunez

Format: 2 hours lecture per week

Delivery Method: In person Lectures

Module Aims: The major challenge for theoretical physics in the last 50 years has been the search for a unified theory of gravity and quantum mechanics. This module will aim to show why such an understanding is needed to explain how singularities inside black holes can be resolved. The first results in the theory of quantum gravity involve the thermodynamics of black holes and the Bekenstein-Hawking entropy. These led to Hawking's prediction that black hole radiate and in the process brought quantum mechanics in direct conflict with general relativity. The module will aim to explain the physics behind these predictions and go on to consider the information loss paradox. Some ideas of the theory of quantum information will be needed to properly understand the issues involved.

Module Content: 1. Survey of geometries, AdS, dS, black holes

2. Penrose diagrams (AdS, extended Schawrzschild and show charged BH case)

3. Singularities in black hole and big bang. Simplified description of singularity theorems, breakdown of general relativity

4. Black hole thermodynamics, second law, Bekenstein-Hawking entropy

5. Simplified description of Hawking radiation

6. Elements of quantum information theory: entanglement and von Neumann entropy, the entropy triangle and monogamy, pure and mixed states

7. Information loss, Page curve. Qualitative picture of islands

8. Elements of holography/string theory

Intended Learning Outcomes: Students will gain an understanding of
- simple geometries including de Sitter and anti de Sitter, extended Schwarzschild and charged black holes
- massless scalar fields in two-dimensional geometries. Simple introduction to quantization and the Fock space
- singularities and why they are unavoidable and the breakdown of general relativity
- in what sense black holes are thermodynamic objects
- the nature and production of Hawking radiation. The Bogoliubov transformation
- the concept of entropy and how it behaves in black hole evaporation
- the meaning of an entanglement island and how the Page curve can be derived
- a qualitative understanding of holography and string theory

Assessment: Coursework 1 (100%)
Resit Assessment: Coursework reassessment instrument (100%)

Assessment Description: Module will be assessed by 100% continuous assessment which will include a presentation element and demonstration of problem solving skills

Moderation approach to main assessment: Universal second marking as check or audit

Assessment Feedback: Canvas will be the primary method for returning feedback. Coursework will be submitted via canvas and marked. Students work will be annotated and returned after marking.

Failure Redemption: As a final year module students would not normally be given an opportunity to redeem failure.

For students who are awarded a first sit, replacement coursework and or presentation will be set for the August resit period.

Additional Notes: available to visiting and exchange students with suitable experience

PH-M32 Quantum Information Processing

Credits: 10 Session: 2022/23 January-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Prof GAP Aarts

Format: 22 lectures, 3 feedback sessions

Delivery Method: Lectures and feedback sessions.

Module Aims: The basic concepts of quantum mechanics, quantum algorithms and quantum computers are introduced. Students will reach an understanding of some of today’s most relevant quantum algorithms, including Grover's search algorithm and Shor’s algorithm for factoring, as well as quantum teleportation and quantum cryptography protocols. Various state-of-the-art experimental realisations of prototype quantum computers based on photons, trapped ions and superconducting qubits, as well as modern developments such as quantum error correction and the D-Wave quantum machine will be discussed.

Module Content: 1. Module introduction and overview

2. Brief history of quantum information and computation

3. Basics of quantum mechanics - two-state systems
• Hilbert spaces
• Spin-1/2 particles and qubits
• Bras & kets
• Quantum measurement

4. The Deutsch algorithm
• Quantum parallelism, interference and quantum speedup

5. Quantum computing basics
• Qubits and quantum logic gates
• Bell states and entanglement
• The no-cloning theorem
• Dense coding
• Universality of quantum gates

6. Quantum teleportation
• Theory and experimental realisations

7. Speeding up database search
• A brief tour through complexity classes
• Grover's quantum search algorithm

8. Quantum cryptography
• Private key cryptography
• Quantum key distribution protocols

9. Shor's quantum algorithm for fast factoring of large numbers
• Quantum Fourier transform
• Order finding and breaking RSA encryption

10. Physical realisations of quantum computers
• Photons, trapped ions, superconductors

11. Protecting quantum information: quantum error correction
• The challenge of decoherence
• Quantum error correcting codes

12. Modern Topics in Quantum Information Processing
• Adiabatic quantum computing
• The D-Wave machine – a real quantum computer? A critical assessment
• Topological quantum error correction

Intended Learning Outcomes: At the end of this module students should be able to demonstrate knowledge of quantum mechanical principles and how they can be used in quantum algorithms and to implement quantum computers.

They will have developed the ability to (i) read, understand and construct quantum circuits, and will have gained a solid understanding of (ii) algorithms and problems, which can be solved efficiently on quantum computers, (iii) basic concepts in information theory, including entanglement and quantum speedup, (iv) and of physical realisations of prototype quantum computers.

Students will be able to perform calculations and solve problems based on the content of this module taking the form of analytical and/or numerical calculations, define and summarize important terms and concepts, recall key formulae, without the use of text books or other sources.

Thereby, students will at the end of the module also have developed a sufficiently broad background to allow them to critically assess news and articles on novel developments in the growing field of quantum computing and quantum technologies, which they come across in outreach publications, scientific media, TV, internet and social media.

Assessment:	Examination 1 (70%)
	Coursework 1 (30%)
Resit Assessment:	Examination (Resit instrument) (100%)

Assessment Description: Examination (70%): 2 hour written exam.
Continuous Assessment (20%): 2 pieces of coursework
Engagement Exercises (10%): 3 exercises

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Not available to visiting and exchange students.

PH-M35 Medical Imaging and Spectroscopy: From MRI to photonics

Credits: 10 Session: 2022/23 January-June

Pre-requisite Modules:

Co-requisite Modules:

Lecturer(s): Dr SM Shermer

Format: Lectures and feedback sessions.

Delivery Method: Lectures, problem solving and revision sessions, practical lab sessions.

Module Aims: Imaging using a variety of modalities from x-rays to magnetic resonance to photonics have revolutionized many areas of science including chemistry, materials and medicine. This course will give an overview of imaging techniques used in medicine. Selected modalities such as magnetic resonance imaging (MRI) and spectroscopy and optical imaging and spectroscopy will be explored in depth. Physical principles of nuclear magnetic resonance, MRI hardware, pulse sequences, safety and applications will be explored. Different types of optical microscopy and spectroscopy will be discussed and the interaction of photons with nano-particles and quantum dots and their applications for imaging will be explored.

Module Content: "Overview of medical imaging techniques (x-rays, ultrasound, MRI, etc)

Nuclear magnetic resonance, MR Hardware and Safety
Pulse sequences for MRI and Spectroscopy
Analysis and interpretation of imaging and spectroscopy data
Modelling, simulation and optimization of NMR systems

Optical microscopy and spectroscopy
Wide-field, confocal, fluorescence microscopy
Optical and Raman spectroscopy
Properties of nanoparticles and quantum dots
Applications in imaging and spectroscopy"

Intended Learning Outcomes: "After completing this module the student should be able to demonstrate a knowledge and understanding of:
* different imaging modalities from x-rays to MRI to photonics
* imaging hardware and function of key components
* nuclear magnetic resonance (Lamor frequency, relaxation effects, field gradients etc)
* optical microscopy and spectroscopy techniques
* special properties of nano-particles and quantum dots and their uses in imaging.

Students should also develop an ability to:
* perform basic calculations such as resonance frequency, gradients, pulse energies, etc.
* explain pulse sequences such as gradient echo, spin echo, pulsed gradient spin echo, PRESS, STEAM
* interpret MR spectra and perform analysis
* numerically model nanoscale phenomena and examine applications
* understand how to characterize and compare nanoscale structures"

Assessment: Coursework 1 (100%)
Resit Assessment: Coursework reassessment instrument (100%)

Assessment Description: Continuous Assessment (100%): 2 pieces of coursework

Moderation approach to main assessment: Second marking as sampling or moderation

Assessment Feedback: Students receive assessed work back with the point of error indicated.
Students have a feedback session to go through solutions to the problems.
Students can arrange with lecturer to have personal feedback on their assessments.

Failure Redemption: Re-sit, if applicable.

Additional Notes: Delivery of both teaching and assessment will be blended including live and self-directed activities online and on-campus.

Available to visiting and exchange students.