Theoretical Physics with a Year Abroad

MPhys

COURSE DETAILS

- A level requirements: AAB
- UCAS code: F345
- Study mode: Full-time
- Length: 5 years

KEY DATES

- Apply by: 31 January 2024
- Starts: 23 September 2024

Course overview

Combining the study of Physics and Mathematics in your degree programme will give you a strong foundation for your future career. You will learn mathematical techniques to help you deal with new ideas and will understand new concepts such as quantum mechanics and relativity. This four year courses means you will graduate with a Master's qualification.

INTRODUCTION

Mathematics is a fascinating, beautiful and diverse subject to study. It underpins a wide range of disciplines; from physical sciences to social science, from biology to business and finance.

Physics is the most fundamental of the sciences. New concepts, such as quantum mechanics and relativity, are introduced at degree level in order to understand nature at the deepest level. These theories have profound philosophical implications because they challenge our view of the everyday world. At the same time they have a huge impact on society since they underpin the technological revolution.

Combining the study of Physics and Mathematics in your degree programme will give you a strong mathematical training. You will learn mathematical techniques to help you to deal with new ideas that often seem counterintuitive, such as string theory, black holes, superconductors and chaos theory.

Physics and Mathematics degrees are highly prized and our graduates have excellent career opportunities.

With this degree programme you also have the option to spend your third year abroad, an incredible opportunity to spend one academic year at one our partner universities expanding your academic and cultural horizons.

WHAT YOU'LL LEARN

- Numeracy
- Problem solving skills
- Ability to reason and communicate clearly
- Teamwork
- Presentation skills

Course content

Discover what you'll learn, what you'll study, and how you'll be taught and assessed.

YEAR ONE

In your first year you will take core mathematics modules, a module in Newtonian Mechanics, and physics modules. After passing the first year, you have the flexibility of transferring to Mathematics or Physics if you wish, subject to approval.

COMPULSORY MODULES

CALCULUS I (MATH101)

Credits: 15 / Semester: semester 1

At its heart, calculus is the study of limits. Many quantities can be expressed as the limiting value of a sequence of approximations, for example the slope of a tangent to a curve, the rate of change of a function, the area under a curve, and so on. Calculus provides us with tools for studying all of these, and more. Many of the ideas can be traced back to the ancient Greeks, but calculus as we now understand it was first developed in the 17th Century, independently by Newton and Leibniz. The modern form presented in this module was fully worked out in the late 19th Century. MATH101 lays the foundation for the use of calculus in more advanced modules on differential equations, differential geometry, theoretical physics, stochastic analysis, and many other topics. It begins from the very basics – the notions of real number, sequence, limit, real function, and continuity – and uses these to give a rigorous treatment of derivatives and integrals for real functions of one real variable.

CALCULUS II (MATH102)

Credits: 15 / Semester: semester 2

This module, the last one of the core modules in Year 1, is built upon the knowledge you gain from MATH101 (Calculus I) in the first semester. The syllabus is conceptually divided into three parts: Part I, relying on your knowledge of infinite series, presents a thorough study of power series (Taylor expansions, binomial theorem); part II begins with a discussion of functions of several variables and then establishes the idea of partial differentiation together with its various applications, including chain rule, total differential, directional derivative, tangent planes, extrema of functions and Taylor expansions; finally, part III is on double integrals and their applications, such as finding centres of mass of thin bodies. Undoubtedly, this module, together with the other two core modules from Semester 1 (MATH101 Calculus I and MATH103 Introduction to linear algebra), forms an integral part of your ability to better understand modules you will be taking in further years of your studies.

FOUNDATIONS OF QUANTUM PHYSICS (PHYS104)

Credits: 15 / Semester: semester 2

This module illustrates how a series of fascinating experiments, some of which physics students will carry out in their laboratory courses, led to the realisation that Newtonian mechanics does not provide an accurate description of physical reality. As is described in the module, this failure was first seen in interactions at the atomic scale and was first seen in experiments involving atoms and electrons. The module shows how Newton's ideas were replaced by Quantum mechanics, which has been critical to explaining phenomena ranging from the photo-electric effect to the fluctuations in the energy of the Cosmic Microwave Background. The module also explains how this revolution in physicist's thinking paved the way for developments such as the laser.

INTRODUCTION TO COMPUTATIONAL PHYSICS (PHYS105)

Credits: 7.5 / Semester: semester 1

The "Introduction to computational physics" (Phys105) module is designed to introduce physics students to the use of computational techniques appropriate to the solution of physical problems. No previous computing experience is assumed. During the course of the module, students are guided through a series of structured exercises which introduce them to the Python programming language and help them acquire a range of skills including: algorithm development; Manipulating and plotting data in a variety of ways; simple Monte Carlo techniques. The exercises are based around the content of the first year physics modules, both encouraging students to recognise the relevance of computing to their physics studies and enabling them to develop a deeper understanding of aspects of their first year course.

INTRODUCTION TO LINEAR ALGEBRA (MATH103)

Credits: 15 / Semester: semester 1

Linear algebra is the branch of mathematics concerning vector spaces and linear mappings between such spaces. It is the study of lines, planes, and subspaces and their intersections using algebra.

Linear algebra first emerged from the study of determinants, which were used to solve systems of linear equations. Determinants were used by Leibniz in 1693, and subsequently, Cramer's Rule for solving linear systems was devised in 1750. Later, Gauss further developed the theory of solving linear systems by using Gaussian elimination. All these classical themes, in their modern interpretation, are included in the module, which culminates in a detailed study of eigenproblems. A part of the module is devoted to complex numbers which are basically just planar vectors. Linear algebra is central to both pure and applied mathematics. This module is an essential pre-requisite for nearly all modules taught in the Department of Mathematical Sciences.

NEWTONIAN MECHANICS (MATH122)

Credits: 15 / Semester: semester 2

This module is an introduction to classical (Newtonian) mechanics. It introduces the basic principles like conservation of momentum and energy, and leads to the quantitative description of motions of bodies under simple force systems. It includes angular momentum, rigid body dynamics and moments of inertia. MATH122 provides the foundations for more advanced modules like MATH228, 322, 325, 326, 423, 425 and 431.

PRACTICAL SKILLS FOR MATHEMATICAL PHYSICS (PHYS156)

Credits: 7.5 / Semester: semester 2

This is a practical-based module exclusively for students taking joint maths and physics degree programmes. In the sessions you will work through progressively more challenging experiments with increasingly complex equipment. You may work alone or in a pair, but you will be supported by a demonstrator who will give you a lot of feedback on your work. In the classes you will be expected to contribute to class discussions and put your results on a whiteboard. There is an assessment associated with each laboratory practical. Again, there will be a variety of activities that will allow you to demonstrate different parts of your learning. You will also have to write at least two full reports for which you will receive written and verbal feedback.

THERMAL PHYSICS AND PROPERTIES OF MATTER (PHYS102)

Credits: 15 / Semester: semester 1

Einstein said in 1949 that "Thermodynamics is the only physical theory of universal content which I am convinced, within the areas of applicability of its basic concepts, will never be overthrown." In this module, different aspects of thermal physics are addressed: (i) classical thermodynamics which deals with macroscopic properties, such as pressure, volume and temperature – the underlying microscopic physics is not included; (ii) kinetic theory of gases describes the properties of gases in terms of probability distributions associated with the motions of individual molecules; and (iii) statistical mechanics which starts from a microscopic description and then employs statistical methods to derive macroscopic properties. The laws of thermodynamics are introduced and applied.

ELECTRICITY, MAGNETISM AND WAVES (PHYS103)

Credits: 15 / Semester: semester 2

Electricity, Magnetism and Waves lie at the heart of physics, being phenomena associated with almost every branch of physics including quantum physics, nuclear physics, condensed matter physics and accelerator physics, as well as numerous applied aspects of physics such as communications science. The course is roughly divided into two sections. The first part introduces the fundamental concepts and principles of electricity and magnetism at an elementary level and develops the integral form of Maxwell's equations. The second part involves the study of oscillations and waves and focuses on solutions of the wave equation, the principles of superposition, and examples of wave phenomena.

YEAR TWO

All modules in year two are compulsory.

COMPULSORY MODULES

CLASSICAL MECHANICS (MATH228)

Credits: 15 / Semester: semester 2

This module is concerned with the motion of physical bodies both in everyday situations and in the solar system. To describe motion, acceleration and forces you will need background knowledge of calculus, differentiation, integration and partial derivatives from MATH101 (Calculus I), MATH102 (Calculus II) and MATH103 (Introduction to Linear Algebra). Classical mechanics is important for learning about modern developments such as relativity (MATH326), quantum mechanics (MATH325) and chaos and dynamical systems (MATH322). This module will make you familiar with notions such as energy, force, momentum and angular momentum which lie at the foundations of applied mathematics problems.

COMPLEX FUNCTIONS (MATH243)

Credits: 15 / Semester: semester 1

This module introduces students to a surprising, very beautiful theory having intimate connections with other areas of mathematics and physical sciences, for instance ordinary and partial differential equations and potential theory.

VECTOR CALCULUS WITH APPLICATIONS IN FLUID MECHANICS (MATH225)

Credits: 15 / Semester: semester 1

This module provides an introduction to the subjects of fluid mechanics and electromagnetism, to the various vector integrals, the operators div, grad and curl and the relations between them and to the many applications of vector calculus to physical situations.

ELECTROMAGNETISM I (PHYS201)

Credits: 15 / Semester: semester 2

The study of classical electromagnetism, one of the fundamental physical theories. Several simple and idealised systems will be studied in detail, developing an understanding of the principles underpinning several applications, and setting the foundations for the understanding of more complex systems. Mathematical methods shall be developed and exercised for the study of physical systems.

CONDENSED MATTER PHYSICS (PHYS202)

Credits: 15 / Semester: semester 2

Condensed matter physics (CMP) is the study of the structure and behaviour of matter that makes up most of the things that surround us in our daily lives, including the screen on which you are reading this material. It is not the study of the very small (particle and nuclear physics) or the very large (astrophysics and cosmology) but of the things in between. CMP is concerned with the "condensed" phases of real materials that arise from electromagnetic forces between the constituent atoms, and at its heart is the necessity to understand the behaviour of these phases by using physical laws that include quantum mechanics, electromagnetism and statistical mechanics. Understanding such behaviour leads to the design of novel materials for advanced technological devices that address the challenges that face modern civilization, such as climate change.

QUANTUM AND ATOMIC PHYSICS I (PHYS203)

Credits: 15 / Semester: semester 1

The course aims to introduce 2nd year students to the concepts and formalism of quantum mechanics. The Schrodinger equation is used to describe the physics of quantum systems in bound states (infinite and finite well potentials, harmonic oscillator, hydrogen atoms, multi-electron atoms) or scattering (potential steps and barriers). Basis of atomic spectroscopy are also introduced.

NUCLEAR AND PARTICLE PHYSICS (PHYS204)

Credits: 15 / Semester: semester 1

This module introduces the basic properties of particles and nuclei, their stability, modes of decay, reactions and conservation laws. Recent research in particle physics is highlighted, and for nuclear physics some of the applications (such as nuclear power) are given. This module leads on to more specialist optional modules in Year 3, in particle physics, nuclear physics and nuclear power.

DIFFERENTIAL EQUATIONS (MATH221)

Credits: 15 / Semester: semester 2

Differential equations play a central role in mathematical sciences because they allow us to describe a wide variety of real-world systems and the mathematical techniques encountered in this module are useful to a number of later modules; this is why MATH201 is compulsory for a number of degree programmes. The module will aim to stress the importance of both theory and applications of ordinary differential equations (ODEs) and partial differential equations (PDEs), putting a strong emphasis on problem solving and examples. It has broadly 5 parts and each part contains two types of equations: those that can be solved by specific methods and others that cannot be solved but can only be studied to understand some properties of the underlying equations and their solutions. The main topics are first order ODEs, second order ODEs, systems of ODEs, first-order PDEs and some of the most well-known second-order PDEs, namely the wave, heat and Laplace equations.

Programme details and modules listed are illustrative only and subject to change.

YEAR ABROAD (YEAR THREE)

You are required to spend the year abroad on an approved placement at a European or overseas partner institution.

Programme details and modules listed are illustrative only and subject to change.

YEAR FOUR

Exactly one of the modules MATH325 and PHYS361 must be taken. Exactly one of the project modules MATH334 and PHYS305 must be taken.

COMPULSORY MODULES

FURTHER METHODS OF APPLIED MATHEMATICS (MATH323)

Credits: 15 / Semester: semester 1

Ordinary and partial differential equations (ODEs and PDEs) are crucial to many areas of science, engineering and finance. This module addresses methods for, or related to, their solution. It starts with a section on inhomogeneous linear second-order ODEs which are often required for the solution of higher-level problems. We then generalize basic calculus by considering the optimization of functionals, e.g., integrals involving an unknown function and its derivatives, which leads to a wide variety of ODEs and PDEs. After those systems of two linear first-order PDEs and second-order PDES are classified and reduced to ODEs where possible. In certain cases, e.g., `elliptic' PDEs like the Laplace equation, such a reduction is impossible. The last third of the module is devoted to two approaches, conformal mappings and Fourier transforms, which can be used to obtain solutions of the Laplace equation and other irreducible PDEs.

RELATIVITY (MATH326)

Credits: 15 / Semester: semester 1

Einstein's theories of special and general relativity have introduced a new concept of space and time, which underlies modern particle physics, astrophysics and cosmology. It makes use of, and has stimulated the development of modern differential geometry. This module develops the required mathematics (tensors, differential geometry) together with applications of the theory to particle physics, black holes and cosmology. It is an essential part of a programme in theoretical physics.

OPTIONAL MODULES

QUANTUM MECHANICS (MATH325)

Credits: 15 / Semester: semester 1

The development of Quantum Mechanics, requiring as it did revolutionary changes in our understanding of the nature of reality, was arguably the greatest conceptual achievement of all time. The aim of the module is to lead the student to an understanding of the way that relatively simple mathemactics (in modern terms) led Bohr, Einstein, Heisenberg and others to a radical change and improvement in our understanding of the microscopic world.

QUANTUM AND ATOMIC PHYSICS II (PHYS361)

Credits: 15 / Semester: semester 1

This module concerns the study of quantum mechanics and its application to atomic systems. The description of simple systems will be covered before extending to real systems. Perturbation theory will be used to determine the detailed physical effects seen in atomic systems.

INTRODUCTION TO STRING THEORY (MATH423)

Credits: 15 / Semester: semester 2

String theory provides a mathematically consistent framework for the unification of gravity and the gauge interactions. It is an area of intense contemporary theoretical and mathematical physics research with the aim of formulating a consistent theory of quantum gravity, the "holy grail" of Theoretical Physics. This module covers the bosonic string from the non-relativistic case to modern quantised relativistic bosonic string. Students are introduced to many of the modern ideas in Particle Physics and string theory at an accessible level.

COMPUTATIONAL MODELLING (PHYS305)

Credits: 15 / Semester: semester 2

Computational methods are at the heart of many modern physics experiments and mastering these techniques is invaluable also beyond fundamental research. In this module we introduce students to object-oriented concepts of a modern programming language (Python) and employ this to model experiments. A combination of Monte Carlo methods (based on random trials) and deterministic methods to solve differential equations are used. Students will then apply their knowledge in a small-group project connected to the state-of-the-art research done in the department. The project topics are taken from different areas of particle, nuclear or accelerator physics and range from analyses situated at the Large Hadron Collider to medical applications of proton beams.

PHYSICS INTERNSHIP (PHYS309)

Credits: 15 / Semester: summer

The physics internship module is designed to give students the experience of working in a STEM related working environment or setting that is different from any project work that they undertake in the Department of Physics. It should provide an insight into how students may apply skills and experiences later in their career; whether working abroad or in any other non-UoL, off-campus scientific or secondary school setting.

CARTESIAN TENSORS AND MATHEMATICAL MODELS OF SOLIDS AND VISCOUS FLUIDS (MATH324)

Credits: 15 / Semester: semester 1

This module provides an introduction to basic concepts and principles of continuum mechanics. Cartesian tensors are introduced at the beginning of the module, bringing simplicity and versatility to the analysis. The module places emphasis on the importance of conservation laws in integral form, and on the fundamental role integral conservation laws play in the derivation of partial differential equations used to model different physical phenomena in problems of solid and fluid mechanics.

MATHEMATICAL PHYSICS PROJECT (MATH334)

Credits: 15 / Semester: semester 2

This is one of the project choices for students in Year 3 of MMath Mathematical Physics (FGH1) and MPhys Theoretical Physics (F344) degree programmes, the other choice being the Physics project module PHYS305. Students perform research in an interesting topic in Mathematical Physics under the supervision of a member of staff, which is followed by preparation of a report and an oral presentation. This project will provide insights into more advanced subjects and experience in handling specialist literature.

NUMERICAL METHODS FOR ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS (MATH336)

Credits: 15 / Semester: semester 2

Many real-world systems in mathematics, physics and engineering can be described by differential equations. In rare cases these can be solved exactly by purely analytical methods, but much more often we can only solve the equations numerically, by reducing the problem to an iterative scheme that requires hundreds of steps. We will learn efficient methods for solving ODEs and PDEs on a computer.

PRACTICAL PHYSICS III (PHYS306)

Credits: 15 / Semester: semester 1

Year 3 Laboratory.

SOLID STATE PHYSICS (PHYS363)

Credits: 7.5 / Semester: semester 1

Condensed Matter Physics (CMP) is the largest subfield of physics with practical applications that has changed our everyday life such as semiconductor devices, magnetic recording disks, Magnetic resonance imaging. It deals with the study of the structure and physical properties of large collection of atoms that compose materials, which are found in nature or synthesized in laboratory. This particular module aims to advance and extend the concepts on solids introduced in Year 1 and Year 2 modules. Especially, it focuses on the atomic structure and behaviour of electrons in crystalline materials, which are essential for understanding of physical phenomena in complex systems.

NUCLEAR PHYSICS (PHYS375)

Credits: 7.5 / Semester: semester 1

This module gives an introduction to nuclear physics. Starting from the bulk properties of atomic nuclei different modes of radioactivity are discussed, before a closer look at the nucleon-nucleon interaction leads to the development of the shell model. Collective models of the nucleus leading to a quantitative understanding of rotational and vibrational excitations are developed. Finally, electromagnetic decays between excited states are introduced as spectroscopic tools to probe and understand nuclear structure.

MATERIALS PHYSICS AND CHARACTERISATION (PHYS387)

Credits: 7.5 / Semester: semester 1

Preparation and characterisation of a range of materials of scientific and technological importance.

SEMICONDUCTOR APPLICATIONS (PHYS389)

Credits: 7.5 / Semester: semester 1

This module develops the physics concepts describing semiconductors in sufficient details for the purpose of understanding the construction and operation of common semiconductor devices.

STATISTICS FOR PHYSICS ANALYSIS (PHYS392)

Credits: 15 / Semester: semester 1

Statistical Methods in Physics Analysis: Understanding Statistics and its application to data analysis

STATISTICAL PHYSICS (PHYS393)

Credits: 7.5 / Semester: semester 2

The problem to understand blackbody radiation opened the door to modern physics. In this module an understanding of thermodynamics is developed from a quantum mechanical and statistical description of the three fundamental gases: The Maxwell-Boltzmann ideal gas in the classical limit, and the Fermi-Dirac and Bose-Einstein gases in the quantum limits for fermions and bosons, respectively. A statistical understanding of thermodynamic quantities will be developed together with a method of deriving thermodynamic potentials from the properties of the quantum system. Applications are shown in solid state physics and the Planck blackbody radiation spectrum.

STATISTICAL PHYSICS (MATH327)

Credits: 15 / Semester: semester 2

Statistical Physics is a core subject in Physics and a cornerstone for modern technologies. To name just one example, quantum statistics is informing leading edge developments around ultra-cold gases and liquids giving rise to new materials. The module will introduce foundations of Statistical Physics and will develop an understanding of the stochastic roots of thermodynamics and the properties of matter. After successfully completing this module students will understand statistical ensembles and related concepts such as entropy and temperature, will understand the properties of classical and quantum gases, will be know the laws of thermodynamics and will be aware of advanced phenomena such as phase transition. The module will also develop numerical computer programming skills for the description of macroscopic effects such as diffusion by an underlying stochastic process.

GAME THEORY (MATH331)

Credits: 15 / Semester: semester 2

In this module you will explore, from a game-theoretic point of view, models which have been used to understand phenomena in which conflict and cooperation occur and see the relevance of the theory not only to parlour games but also to situations involving human relationships, economic bargaining (between trade union and employer, etc), threats, formation of coalitions, war, etc.

THE MAGIC OF COMPLEX NUMBERS: COMPLEX DYNAMICS, CHAOS AND THE MANDELBROT SET (MATH345)

Credits: 15 / Semester: semester 2

A "dynamical system" is a system that changes over time according to a fixed rule. In complex dynamics, we consider the case where the state of the system is described by a single (complex) variable, and the rule of evolution is given by a holomorphic function. It turns out that this seemingly simple setting leads to very rich, subtle and intricate problems, some of which are still the subject of ongoing mathematical research, both at the University of Liverpool and internationally. This module will provide an introduction to this fascinating subject, and introduce students to some of these problems. In the course of this study, we will encounter many results about complex functions that may seem "magic" when compared with what might be expected from real analysis. A highlight of this kind is the theorem that every polynomial is "chaotic" on its Julia set. We will also see how this "magic" can help us understand phenomena that at first seem to have no connection with complex numbers at all.

DIFFERENTIAL GEOMETRY (MATH349)

Credits: 15 / Semester: semester 1

Differential geometry studies distances and curvatures on manifolds through differentiation and integration. This module introduces the methods of differential geometry on the concrete examples of curves and surfaces in 3-dimensional Euclidean space. The module MATH248 (Geometry of curves) develops methods of differential geometry on examples of plane curves. This material will be discussed in the first weeks of the course, but previous familiarity with these methods is helpful. Students following a pathway in theoretical physics might find this module interesting as it discusses a different aspect of differential geometry, and might take it together with MATH326 (Relativity). MATH410 (Manifolds, homology and Morse theory) and MATH446 (Lie groups and Lie algebras).

ELECTROMAGNETISM II (PHYS370)

Credits: 15 / Semester: semester 2

The module builds on first and second year modules on electricity, magnetism and waves to show how a wide variety of physical phenomena can be explained in terms of the properties of electromagnetic radiation. The module will also explore how these properties follow from the relationships between electric and magnetic fields (and their interactions with matter) expressed by Maxwell's equations, and how electromagnetism fits into the theory of Special Relativity.

RELATIVITY AND COSMOLOGY (PHYS374)

Credits: 15 / Semester: semester 2

The course covers the concepts required to connect special relativity, Newtonian gravity, general relativity, and the cosmological metrics and dynamical equations. The main part of the course is focussed on cosmology, which is study of the content of the universe, structure on the largest scales, and its dynamical evolution. This is covered from both a theoretical and observational perspective.

PARTICLE PHYSICS (PHYS377)

Credits: 7.5 / Semester: semester 2

Introduction to Particle Physics. To build on the second year module involving Nuclear and Particle Physics. To develop an understanding of the modern view of particles, of their interactions and the Standard Model.

SURFACES AND INTERFACES (PHYS381)

Credits: 7.5 / Semester: semester 2

 This module gives a brief introduction into the physics of solid surfaces their experimental study. Surfaces and interfaces are everywhere and many surface-related phenomena are common in daily life (texture, friction, surface-tension, corrosion, heterogeneous catalysis). Here we are concerned with understanding the microscopic properties of surfaces, asking questions like: what is the atomic structure of the surface compared to that of the bulk? What happens to the electronic properties and vibrational properties upon creating a surface? What happens in detail when we adsorb an atom or a molecule on a surface? This module will mostly concentrate on simple model systems like the clean and defect-free surface of a single-crystal substrate.

NUCLEAR POWER (PHYS376)

Credits: 7.5 / Semester: semester 2

This module focuses on nuclear reactors as a source of energy for use by society. After reviewing the underlying physics principles, the design and operation and nuclear fission reactors is introduced. The possibility of energy from nuclear fusion is then discussed, with the present status and outlook given.

ENERGY GENERATION AND STORAGE (PHYS372)

Credits: 7.5 / Semester: semester 2

Producing sufficient energy to meet the demands of an expanding and increasingly power-hungry society, whilst striving not to exacerbate the impacts of climate change, is a significant challenge. This module looks at the key physical concepts which underpin a range of energy generation sources, from traditional fossil fuel fired turbine generation to photovoltaic solar cells. This builds on prior knowledge of thermodynamics, fluid behaviour and semiconductors to show how these concepts can be practically applied to power generation and storage systems.

MAGNETIC PROPERTIES OF SOLIDS (PHYS399)

Credits: 7.5 / Semester: semester 2

The magnetic properties of solids are exploited extensively in a wide range of technologies, from hard disk drives, to sensors, to magnetic resonance imaging, and the development of magnetic materials is a multi-billion pound industry. Fundamentally, magnetism in condensed matter also represents one of the best examples of quantum mechanics in action, even at room temperature and on a macroscopically observable scale. In this module we will explore how the interactions between electrons in solids can result in the magnetic moment, and how this relates to the quantum mechanical property of spin. We will use these tools to probe the complicated processes that allow spontaneous magnetism to exist within certain select materials, and their implications for future technologies and our theoretical understanding of the nature of solids.

INTRODUCTION TO MODERN PARTICLE THEORY (MATH431)

Credits: 15 / Semester: semester 2

Modern particle theory is combining special relativity, quantum mechanics and field theory to describe all the fundamental subatomic particles and their interactions. The module develops the relevant concepts that enter into the Standard Model of particle physics. The key concept in modern physics is that of invariance under local symmetries and the conservation laws that they give rise to. The module covers the basic elements that describe modern particle theory, including: Lorentz and Poincare symmetries, which underlie special relativity; Hamilton and Lagrange formalism of classical mechanics and fields, which underlie the modern formalism; basic elements of relativistic quantum mechanics including the Dirac and Klein-Gordon equations; field quantisation; global and local symmetries; global and local symmetry breaking and the Higgs mechanism; unitary groups and the classification of elementary particles; basic elements of grand unified theories and phenomenological aspects. The students will be introduced to many of the modern ideas in Particle Physics at an accessible level.

MATHEMATICAL BIOLOGY (MATH335)

Credits: 15 / Semester: semester 1

In the current age of big data, mathematics is becoming indispensable in order for us to make sense of experimental results and in order to gain a deeper understanding into mechanisms of complex biological systems. Mathematical models can provide insights that cannot be gained through experimental work alone. This module will focus on teaching students how to construct and analyse models for a wide range of biological systems. Mathematical approaches covered will be widely applicable.

NETWORKS IN MATHEMATICAL BIOLOGY (MATH338)

Credits: 15 / Semester: semester 2

Networks are familiar to us from many real-world systems such as the internet, power grids, transportation and biological networks. The underpinning mathematical concept is called a graph an it is no surprise that the same issues arise in each area, whether this is to identify the most important or influential individuals in the network, or to prevent dynamics on the network (e.g. epidemics) or to make the network robust to the dynamics it supports (e.g. power grids and transportation). In this module, we learn about different classes of networks and how to quantify and describe them including their structures and their nodes. Much of our detailed understanding of networks and their features will come from analysis of idealised random networks which nevertheless are often good representations of those seen in the real world. We will consider real-world biological applications of network theory, in particular focusing on epidemics.

Programme details and modules listed are illustrative only and subject to change.

YEAR FIVE

You will choose optional modules below to make up a total of 75 credits, with more than 37.5 credits being from PHYS modules.

COMPULSORY MODULES

ADVANCED QUANTUM PHYSICS (PHYS480)

Credits: 15 / Semester: semester 1

Modern concepts and advanced quantum mechanics problems will be discussed in depth and supported by complex calculations. In the course it will be demonstrated that quantum mechanics is an extraordinary successful theory describing nature, i.e. part of the course emphasis is on applications of quantum physics and state-of-the art experiments, but not always in full detail.

MATHEMATICAL PHYSICS PROJECT (MATH420)

Credits: 30 / Semester: whole session

This is a compulsory two-semester essay project for students in Year 4 of the FGH1 Mathematical Physics MMath or F344 Theoretical Physics MPhys degree programmes. Research is performed in an advanced interesting topic which should lead to acquiring knowledge useful for potential continuation of mathematical studies through a PhD.

One of MATH334 or PHYS305 is a pre-requisite to MATH420. Students who took MATH334 project module in Year 3 have the opportunity to continue research in the same topic.

OPTIONAL MODULES

LINEAR DIFFERENTIAL OPERATORS IN MATHEMATICAL PHYSICS (MATH421)

Credits: 15 / Semester: semester 1

This module is concerned with linear partial differential equations (PDEs) that arise in mathematical physics, and advanced methods for solving them. There is a particular focus on methods that use singular solutions, which satisfy the PDE at all but a finite number of points. We will study three canonical PDEs: Laplace's equation, the heat equation and the wave equation. In each case we will see how the solution to complicated problems can be built up from solutions to simpler problems, typically in the form of an infinite series or an integral.

QUANTUM FIELD THEORY (MATH425)

Credits: 15 / Semester: semester 1

Quantum Field Theory provides the mathematical language of modern theoretical particle and condensed matter physics. Historically Quantum Field Theory was developed to be the consistent theory of quantum mechanics and special relativity. The mathematical techniques developed in this course form the theoretical basis for varied fields such as high energy particle physics or superconductivity.

CLASSICAL MECHANICS (PHYS470)

Credits: 15 / Semester: semester 1

The module will build on students' existing knowledge of Newtonian mechanics, and introduce important principles, concepts and techniques from Lagrangian and Hamiltonian mechanics. The core material will be based on systems of particles, but field theory will also be discussed. The focus will be on application of these topics to classical systems, but this will also give some insight into fundamental aspects of modern physics (including quantum mechanics). Delivery will be through lectures and tutorials/problems classes.

ACCELERATOR PHYSICS (PHYS481)

Credits: 7.5 / Semester: semester 1

There are almost 50,000 particle accelerators in the world, ranging from the linear accelerators used for cancer therapy in modern hospitals to the giant 'atom-smashers' at international particle physics laboratories used to unlock the secrets of creation.

Accelerator and beam physics is a broad discipline that draws on concepts from linear and nonlinear mechanics, electrodynamics, special relativity, plasma physics, statistical mechanics, and quantum mechanics.

This course covers the fundamental physical principles of particle accelerators, with a focus on basic beam dynamics and beam diagnostics. It teaches the fundamental concepts of the most commonly used accelerator types, beam motion and diagnostics. The course links these concepts to the current research programmes of the Liverpool Accelerator Group, based at the Cockcroft Institute.

CORRELATED ELECTRON MATERIALS (PHYS486)

Credits: 7.5 / Semester: semester 1

Some of the most intriguing properties of matter arise because of the mutual interaction between electrons, causing correlations between them. Materials which display electron correlations offer great potential for developing new materials for technological applications. However, attempts to explain such phenomena by considering electrons individually largely fail, and enormous effort has been dedicated to developing theories which can account for such unexpected properties of matter. Two of the most well-known and heavily investigated correlated electron phenomena include ferromagnetism and superconductivity. As key examples, here we will explore these effects, building up from phenomenological description to fundamental theory and eventually to describe and plan experimental observations. We will extend these ideas to contemporary strongly correlated electron materials, and the current limitations in our understanding of these materials.

PHYSICAL PRINCIPLES OF MATERIALS (PHYS487)

Credits: 7.5 / Semester: semester 1

This is an advanced module on understanding the behaviour of materials that is suitable for final year Physics undergraduate students. It covers the systematic basis of materials preparation, defects together with point defect and phase behaviour. There are case studies on important classes of materials. The module is complementary to, but does not duplicate, Physics modules about for example the electrical and magnetic properties of solids.

NANOSCALE PHYSICS AND TECHNOLOGY (PHYS499)

Credits: 7.5 / Semester: semester 2

This module introduces the current and active field of nanoscale physics and technology. It will cover basic physics at the nanoscale as well as nanoscale fabrication and characterisation techniques and will discuss a range of applications of nanostructures.

ADVANCED TOPICS IN MATHEMATICAL BIOLOGY (MATH426)

Credits: 15 / Semester: semester 1

Mathematics can be applied to a wide range of biological problems, many of which involve studying how systems change in space and time. In this module, an example selection of mathematical applications will be presented chosen from staff research interests involving developmental biology, epidemic dynamics & biological fluid dynamics.

WAVES, MATHEMATICAL MODELLING (MATH427)

Credits: 15 / Semester: semester 2

This module introduces some of the generic ideas that underpin the analysis of waves in physical systems. Both linear and nonlinear models are discussed. Quasi-linear hyperbolic first-order systems of equations are introduced leading to the study of Riemann invariants, simple waves and shock solutions. Some knowledge of Vector Calculus would be useful.

INTRODUCTION TO STRING THEORY (MATH423)

Credits: 15 / Semester: semester 2

String theory provides a mathematically consistent framework for the unification of gravity and the gauge interactions. It is an area of intense contemporary theoretical and mathematical physics research with the aim of formulating a consistent theory of quantum gravity, the "holy grail" of Theoretical Physics. This module covers the bosonic string from the non-relativistic case to modern quantised relativistic bosonic string. Students are introduced to many of the modern ideas in Particle Physics and string theory at an accessible level.

ASYMPTOTIC METHODS FOR DIFFERENTIAL EQUATIONS (MATH433)

Credits: 15 / Semester: semester 2

This module provides an introduction into perturbation theory for partial differential equations. This theory has a wide, and growing, range of applications in the study of electro-magnetism, elasticity, heat conduction, the propagation of waves, and the study of cracks in materials.

PHYSICS OF LIFE (PHYS482)

Credits: 7.5 / Semester: semester 2

This module begins with a description of the physical conditions necessary for the evolution of life in a universe. It gives an introduction to the physical principles that underpin the organisation and activity of living things including aspects of evolution and ecology. It also gives an introduction to current thinking of how life evolved on earth and of the sensitivity of the biosphere to changes in the earth's orbit and the composition of its atmosphere. It will provide physical insight into the drivers of climate change, the loss of biodiversity, the origin of disease and the spread of bacterial resistant to antibiotics.

ADVANCED NUCLEAR PHYSICS (PHYS490)

Credits: 15 / Semester: semester 2

The Advanced Nuclear Physics course introduces forms of the nucleon-nucleon interaction and the nuclear mean-field potential. Deformation (non-spherical nuclear shapes) is introduced via the deformed shell model (Nilsson model) and collective modes of excitation discussed. Exotic nuclear behaviour at the extremes of spin (angular momentum), isospin (proton-neutron imbalance) and charge/mass (superheavy elements) is presented. Various types of nuclear reaction are discussed, particularly in relation to the astrophysical creation of the elements.

NEUTRINOS AND DARK MATTER (PHYS492)

Credits: 7.5 / Semester: semester 2

Neutrinos are fundamental particles that were thought to be simple massless particles that only experienced the weak interaction. Recent measurements have shown that the neutrino is much more complex and these particles can potentially provide a window into new areas of physics. Observations of the structure of the universe require the existence of a new form of a new form of gravitationally interacting matter known as dark matter. Experiments to detect neutrinos and dark matter both have distinct features to achieve the extremely low backgrounds that are required to measure these particles. This course will discuss the field of neutrinos physics and dark matter and these low background techniques.

ADVANCED PARTICLE PHYSICS (PHYS493)

Credits: 15 / Semester: semester 2

This module looks at how basic calculations are done in particle physics.
Relativistic quantum mechanics and their limitations are introduced and applied to various particle physics problems. Feynman rules are discussed and examples of calculations of cross sections and particle lifetimes are given in the context of electromagnetic, weak and strong interactions. The development of the electroweak theory and the Higgs boson, as well some historical elements and description of current particle physics research are also covered.

INTRODUCTION TO MODERN PARTICLE THEORY (MATH431)

Credits: 15 / Semester: semester 2

Modern particle theory is combining special relativity, quantum mechanics and field theory to describe all the fundamental subatomic particles and their interactions. The module develops the relevant concepts that enter into the Standard Model of particle physics. The key concept in modern physics is that of invariance under local symmetries and the conservation laws that they give rise to. The module covers the basic elements that describe modern particle theory, including: Lorentz and Poincare symmetries, which underlie special relativity; Hamilton and Lagrange formalism of classical mechanics and fields, which underlie the modern formalism; basic elements of relativistic quantum mechanics including the Dirac and Klein-Gordon equations; field quantisation; global and local symmetries; global and local symmetry breaking and the Higgs mechanism; unitary groups and the classification of elementary particles; basic elements of grand unified theories and phenomenological aspects. The students will be introduced to many of the modern ideas in Particle Physics at an accessible level.

Programme details and modules listed are illustrative only and subject to change.

HOW YOU'LL LEARN

Your learning activities will consist of lectures, tutorials, practical classes, problem classes, private study and supervised project work.

In year one, lectures are supplemented by a thorough system of group tutorials and computing work is carried out in supervised practical classes. Key study skills, presentation skills and group work start in first-year tutorials and are developed later in the programme.

The emphasis in most modules is on the development of problem solving skills, which are regarded very highly by employers. Project supervision is on a one-to-one basis, apart from group projects in year two.

HOW YOU'RE ASSESSED

Most modules are assessed by a two and a half hour examination in January or May, but many have an element of coursework assessment. This might be through homework, class tests, mini-project work or key skills exercises.

LIVERPOOL HALLMARKS

We have a distinctive approach to education, the Liverpool Curriculum Framework, which focuses on research-connected teaching, active learning, and authentic assessment to ensure our students graduate as digitally fluent and confident global citizens.

Careers and employability

Physics and Mathematics degrees are highly prized and our graduates have excellent career opportunities in industrial research and development, computing, business, finance and teaching.

Typical types of work our graduates have gone onto include:

* An actuarial trainee analyst
* A graduate management trainee risk analyst
* A trainee chartered accountant.

Recent employers of our graduates are:

* Barclays Bank plc
* Deloitte
* Forrest Recruitment
* Marks and Spencer
* Mercer Human Resource Consulting Ltd.

87.5% OF GRADUATES GO ON TO WORK OR FURTHER STUDY WITHIN 15 MONTHS OF GRADUATION.

Discover Uni, 2018-19.

Fees and funding

Your tuition fees, funding your studies, and other costs to consider.

TUITION FEES

UK fees (applies to Channel Islands, Isle of Man and Republic of Ireland)	
Full-time place, per year	£9,250

International fees	
Full-time place, per year	£27,200

Fees are correct for the academic year 2024/25
Tuition fees cover the cost of your teaching and assessment, operating facilities such as libraries, IT equipment, and access to academic and personal support. [Learn more about tuition fees, funding and student finance](#).

ADDITIONAL COSTS

Your tuition fee covers almost everything but you may have [additional study costs](#) to consider, such as books.

Find out more about the [additional study costs](#) that may apply to this course.

SCHOLARSHIPS AND BURSARIES

We offer a range of scholarships and bursaries to provide tuition fee discounts and help with living expenses while at university.

Check out our [Undergraduate Global Advancement Scholarship](#). This offers a tuition fee discount of up to £5,000 for eligible students starting an undergraduate degree from September 2024. There's also [the Liverpool Bursary](#) which is worth £2,000 per year for eligible students.

[Discover our full range of undergraduate scholarships and bursaries](#)

Entry requirements

The qualifications and exam results you'll need to apply for this course.

Your qualification	Requirements About our typical entry requirements
A levels	AAB Applicants with the Extended Project Qualification (EPQ) are eligible for a reduction in grade requirements. For this course, the offer is **ABB** with **A** in the EPQ. You may automatically qualify for reduced entry requirements through our contextual offers scheme.
GCSE	4/C in English and 4/C in Mathematics
Subject requirements	Applicants must have studied Mathematics at Level 3 within 2 years of the start date of their course. For applicants from England: For science A levels that include the separately graded practical endorsement, a "Pass" is required.
BTEC Level 3 National Extended Diploma	Applications considered. Relevant when combined with A level Mathematics grade A
International Baccalaureate	35 including 6 at higher level in Physics and Mathematics
Irish Leaving Certificate	H1, H1, H2, H2, H2, H3 including Mathematics at H1 and Physics at H2.
Scottish Higher/Advanced Higher	Advanced Highers accepted at grades AAB including grade A in Mathematics and grade B in Physics.

Your qualification	Requirements [About our typical entry requirements](#)
Welsh Baccalaureate Advanced	Acceptable at grade B alongside AA at A level including grade A in Mathematics and grade A in Physics.
Access	Considered
International qualifications	Many countries have a different education system to that of the UK, meaning your qualifications may not meet our entry requirements. Completing your Foundation Certificate, such as that offered by the [University of Liverpool International College](#), means you're guaranteed a place on your chosen course.

ALTERNATIVE ENTRY REQUIREMENTS

- If your qualification isn't listed here, or you're taking a combination of qualifications, [contact us](#) for advice

- [Applications from mature students](#) are welcome.

THE ORIGINAL REDBRICK