SECTION 3

BRIEF COURSE DESCRIPTIONS

1st Year Courses

(all courses are of half-unit value unless stated otherwise)

PHYSICS OF THE UNIVERSE **Code: PHAS1102**
Term: **1**
Pre-requisites:
Structure: **27 lectures, 6 hours of problem classes/discussion**

The course aims to give 1st year students in physics and astronomy an introduction to the modern ideas in physics and astronomy. It introduces the ideas of astrophysics and provides broad coverage of the origin and evolution of the Universe, as it is currently understood.
Topics:
Stellar Astrophysics. Radiation - Planck's Law and Stefan-Boltzmann Law, with astrophysical (stellar) applications, cosmic microwave background. Stars - fusion, with associated nuclear and particle-physics topics. Cosmology and the Universe – introduction to space and time, magnitude scale & colour systems, distance-scale topics, concept of curved space-time, basis of Einstein's approach to gravity, black holes. Cosmological principles, Redshift and Hubble's law, the Big Bang model.

WAVES, OPTICS AND ACOUSTICS **Code: PHAS1224**
Term: **2**
Pre-requisites: **A-Level Physics and Maths or equivalent**
Structure: **27 lectures, 6 hours of problem classes/discussion**

This is a basic course in wave motion, covering both general features of the wave equation and features specific to electromagnetic waves and sound waves. The properties of different types of waves are discussed together with major applications in physical and geometrical optics and propagation of sound waves. At the end of the course the student should be fully conversant with these fundamentals and how they are applied to an understanding of interference and diffraction, dispersion and wave propagation phenomena.
Topics:
General properties of waves. Basic properties of wave equation. Acoustic waves in gases and solids. Resonant properties of strings, pipes and cavities. Moving sources and detectors. Reflection and refraction. Coherence. Interference. Huygens's principle. Fraunhofer diffraction. Lenses and curved mirrors, optical devices. Resolution; Raleigh criterion; Abbe theory.

THERMAL PHYSICS **Code:PHAS1228**
Term: **2**
Pre-requisites: **A-Level Maths and Physics or equivalent**
Structure: **27 lectures, 6 hours of problem classes/discussion**

The course aims to develop, via a discussion of heat and the interaction of heat with matter, an understanding of the laws of thermodynamics. Simple statistical ideas of heat are introduced which are fully developed in a later course. Students are able by the end to apply thermodynamics to simple systems.
Topics:
Atoms, ions and molecules as the building blocks of matter, perfect gas, real gases, the structure of liquids, Molecular, covalent, ionic and metallic solids, phase change, latent heats, triple point and critical point, p-V and p-V-T diagrams, Thermodynamic state, state variables, and thermodynamic equilibrium, Heat Transfer mechanisms, The Carnot cycle, Entropy, disorder, the arrow of time and

the Second Law of Thermodynamics Plausible derivation of the form of the Maxwell-Boltzmann distribution.

PRACTICAL SKILLS 1A **Code: PHAS1130**
Term: **1 & 2**
Pre-requisites:
Structure: **5 lectures (approx.), 90 hours of practical work**

This course gives practice in experimental technique including data recording, data analysis and report writing; also an introduction to the elements of a computer packaged analysis tools.
The astronomy sessions are conducted at the University of London Observatory (ULO) at Mill Hill. Its principal instruments are the 24/18-inch twin Radcliffe refractor and the 24-inch Allen reflector. Instruments for Practical Astronomy teaching for this course include the Fry telescope (8-inch refractor), a 10” Meade reflector and 14” Celestron reflector reserved exclusively for first-year students. Other Meade computer-controlled reflectors, several theodolites, measuring machines and several networked PCs with Internet access and network connections to UCL are available.
The lectures cover basic positional astronomy (co-ordinate systems, spherical trigonometry, time, the night sky) and take place in Gower Street, although one of the lectures is traditionally given at the nearby London Planetarium.
Topics:
Use of telescopes and ancillary astronomical equipment such as CCD cameras and spectroscopes, important concepts in astronomy such as stellar spectral classification, analysis of photographs, measurement of variable stars, and the measurement of spectra, Data Analysis and Computing skills gained in modules of the Physics Laboratory course 1240. Many of the experiments involve the use of prepared material such as data files, CD-ROMs, CCD images or photographic prints; these have been obtained at ULO or from other observatories around the world, including satellites (e.g., Viking Mars Orbiter, Hubble Space Telescope). See http://www.ulo.ucl.ac.uk/students/1b30 for a full description of the course and useful information.

PRACTICAL SKILLS 1C **Code: PHAS1240**
Term: **1 & 2**
Pre-requisites:
Structure: **6+3 Lectures, 70 hours of practical work**

A course giving an introduction to Physics Laboratory techniques and practice, and developing the basic practical skills necessary for performing experimental work which is a crucial component of both the physics-related and astronomy-related Honours Degree programme.
Topics:
General experimental techniques through completion of simple practical exercises; data analysis through lectures, special exercises and application to experiments performed; familiarisation with use of computers covering training on a spreadsheet, word processor and net browser packages, computer programming using a self-directed learning package at workstations, supplemented by lectures.

PRACTICAL SKILLS 1P **Code: PHAS1241**
Term: **2**
Pre-requisites:
Structure: **70 hours of practical work**

This course is a further instruction in experimental physics through a selection of scripted experimental exercises appropriate to the various degree streams providing practice in experimental technique, including data recording, data analysis and report writing.

MATHEMATICAL METHODS I **Code: PHAS1245**
Term: **1**
Pre-requisites: **A-Level Maths or its equivalent**
Structure: **33 lectures, 7 hours of discussion, 5 problem classes**

All the mathematics required for the understanding of 1st Year Astronomy and Physics courses will be provided in this service course and PHAS1246.

Topics

Elementary Functions (mainly revision): Manipulation of algebraic equations, powers, exponentials and logarithms, inverse functions, trigonometric functions, sine, cosine and tangent for special angles, hyperbolic functions.

Differentiation (mainly revision): Definition, product rule, function of a function rule, implicit functions, logarithmic derivative, parametric differentiation, maxima and minima.

Integration (mainly revision): Integration as converse of differentiation, changing variables, integration by parts, partial fractions, trigonometric and other substitutions, definite integral, integral as the area under a curve, trapezium rule, integral of odd and even functions.

Partial Differentiation: Definition, surface representation of functions of two variables, total differentials, chain rule, change of variables, second order derivatives. Maxima, minima and saddle points for functions of two variables.

Vectors: Definition, addition, subtraction, scalar and vector multiplication. Vector and scalar triple products, vector equations (Third order determinants only very briefly). Vector geometry - straight lines and planes. Vector differentiation, vectors in plane polar, cylindrical, and spherical polar coordinates.

Series: Sequences and series, convergence of infinite series. Power series, radius of convergence, simple examples including the binomial series. Taylor and Maclaurin series, L'Hôpital's rule. Complex Numbers: Representation, addition, subtraction, multiplication, division, Cartesian,polar exponential forms, De Moivre's theorem, powers and roots, complex equations.

MATHEMATICAL METHODS II **Code: PHAS1246**
Term: **2**
Pre-requisites: **A-Level Maths or its equivalent**
Structure: **33 lectures, 7 hours of discussion, 5 problem classes**

All the mathematics required for the understanding of 1st Year Astronomy and Physics courses will be provided in this service course and 1245.

Topics:

Multiple Integrals: Line integrals, area and volume integrals, change of coordinates, area and volume elements in plane polar, cylindrical polar and spherical polar coordinates.

Vector Operators: Directional derivatives, gradient for functions of two or three variables. Gradient, divergence, curl and Laplacian operators in Cartesian coordinates, Flux of a vector field, Divergence theorem, Stokes' theorem, Coordinate-independent definitions of vector operators. Derivation of vector operators in spherical and cylindrical polar coordinates.

Differential Equations: Ordinary first-order, separable, integrating factor, change of variables, exact differential.Ordinary second order homogeneous and non-homogeneous including equal roots.

Series Solution of Ordinary Differential Equations: Derivation of the Frobenius method, Application to linear first order equations, Singular points and convergence, Application to second order equations.

Elements of Probability Theory: Discrete probability distributions, moments, means and standard deviations, independent probabilities. Means and standard deviations for continuous distributions.

Special Theory of Relativity: Implications of Galilean transformation for the speed of light

Michelson-Morley experiment, Einstein’s postulates, Derivation of the Lorentz transformation equations; length contraction, time dilation, addition law of velocities, “paradoxes” Transformation of momentum and energy; invariants, Doppler effect for photons, threshold energy for pair production, the headlight effect.

CLASSICAL MECHANICS **Code: PHAS1247**
Term: **1**
Pre-requisites: **A-Level Maths and Physics or equivalent**
Structure: **27 lectures, 10 hours of discussion, 4 problem classes**

This is an introductory course in Classical Mechanics. Starting from Newton’s Law of Motion, it sets up the techniques used to apply the laws to the solution of physical problems. It is essential background for many of the succeeding courses within the degrees in Physics and Astronomy.
Topics:
Introduction to Classical Mechanics: Importance of classical mechanics; conditions for its validity. Statics, kinematics, dynamics; units and dimensions. Newton' s laws of motion.
Motion in one dimension: Variable acceleration. Work, power, impulse. Conservation of momentum and energy; conservative force, potential and kinetic energy. Construction of equations of motion and their solutions. Simple harmonic motion; damped and forced oscillations, resonance.
Motion in two and three dimensions: Relative motion; Galilean and other transformations between frames of reference. Inertial and non-inertial frames of reference, fictitious forces. Motion in a plane; trajectories, elastic collisions. Constraints and boundary conditions. Rotation about an axis; motion in a circle, angular velocity, angular momentum, torques and couples; radial and transverse components of velocity and acceleration in plane polar coordinates, centrifugal and Coriolis forces. Orbital motion for inverse square law of force; statement of the gravitational force due to a spherically symmetric mass distribution. Kepler' s laws of planetary motion (review of properties of conic sections).
Rigid Body Motion: Centre of mass, its motion under the influence of external forces; moment of inertia, theorems of parallel and perpendicular axes; centre of percussion. Rotational analogues of rectilinear equations of motion; simple theory of gyroscope.
Fluid Mechanics: Fluids at rest: pressure, buoyancy and Archimedes principle. Fluids in motion: equation of continuity for laminar flow; Bernoulli's equation with applications, flow over an aerofoil; brief qualitative account of viscosity and turbulence.

PRACTICAL MATHEMATICS 1 **Code: PHAS1449**
Term: **2**
Pre-requisites: **None**
Structure: **27 lectures, 6 hours of problem classes/discussion**

PHAS1449 will provide a foundation in computer-based mathematical modelling for students of Theoretical Physics. It is based on a state of the art system for mathematical computation, and will introduce key concepts in computation which will be developed further and applied to a project in year 2 and will provide important concepts for the optional course in object-oriented computer languages in year 3. At the same time it will reinforce and apply concepts of mathematical physics being taught in other first year courses. There are no prerequisites for this course, but it is itself a prerequisite for PHAS2443 Practical Mathematics in the second year.
***This module is intended for students following the Theoretical Physics degree course.**

Topics
‘Computer Algebra’ systems in general and *Mathematica.*
Mathematica©’s structures (especially lists) and their relationship with mathematical structures. Rules and how to apply them. *Mathematica©’s* pattern constructions. Rules as returned when

solving equations. Manipulating expressions with rules. Graphics: basic line graphs, contour and surface plots. Controlling graph layouts, combining and animating graphs. Applications to visualisation of fields. Conformal Mapping. Domains of functions. More general pattern-matching; sequences, types, criteria and defaults. RepeatReplace and delayed rules. Defining functions. Overloading of functions. Modules. Pure (unnamed) functions. Functions that remember or redefine themselves. Recursive procedures. Loops and control structures. Numerical solutions of algebraic equations using FindRoot and using graphs to control the process. Methods of root-finding by bisection and the Newton-Raphson method. Numerical solution of differential equations by finite difference methods, including simple stability analysis. Use of NDSolve. Repeated operations without loops: Nest, While, Fixed Point, Through, Compositions. Series solution of differential equations. Boundary value problems (multiple shooting). Brief treatment of partial differential equations.Analysis of data: linear and non-linear fitting; Fourier smoothing of data. Reading and writing external files. Simple image processing (pixellisation; edge enhancement).

ESSENTIAL MEDICAL PHYSICS **Code: PHAS1882**

Term: **2**

Pre-requisites: **A-Level Maths and Physics or equivalent**

Structure: **27 lectures, 6 hours of problem classes/discussion**

This course provides foundation knowledge in basic medical statistics and biophysics.

Topics:

Atomic and Molecular Structure; Physics properties of macromolecules; Structure and physical properties of membranes; Molecular Spectroscopy; Nuclear Magnetic Resonance; Medical statistics.

DEVELOPING EFFECTIVE COMMUNICATION 1 **Code: PHAS1901**

Term: **1&2**

Pre-requisites: **None**

Aim of the Course:

This is the first of three modules that aim to develop your skills in getting your message across, and in understanding the messages of others. These skills are crucial not only for being an effective physicist, but also in functioning effectively in many career – or non-career – situations.

Objectives:

After completing this module successfully, students should be able to:

- write short pieces for non-specialist and specialist audiences;
- orally present scientific ideas to a small group of peers;
- construct a personal web page
- use appropriate IT effectively

2nd Year Courses

(All courses are of half-unit value unless stated otherwise)

ASTROPHYSICAL PROCESSES: NEBULAE TO STARS Code: PHAS2112
Term: 2
Pre-requisites: Attending PHAS2228 and PHAS2222
Structure: 27 lectures, 6 hours of problem classes/discussion

The aim of this course is to introduce students to the most important astrophysical processes encountered in a wide range of nebular and stellar environments. A knowledge of these processes is an essential prerequisite for several subsequent more specialised 3rd and 4th year astronomy and astrophysics courses. The philosophy of the course is to start at the low density (nebular) limit, where microscopic processes must be considered individually and to then treat increasingly high density environments, working through to the atmospheres of stars; the interior regions where stellar nuclear energy sources are located; and finally, degenerate matter, the highest density form of material found in stars.
Topics:
Microscopic atomic processes that determine physical conditions such as ionisation balance and temperature in the low-density interstellar medium. Treatment of higher density and higher-temperature environments, where simplifying assumptions can often be made. A range of processes that are encountered in stellar atmospheres and stellar interiors are treated in this part of the course. Finally, the nuclear reaction processes that generate energy in high-temperature stellar cores are discussed.

PHYSICS OF THE SOLAR SYSTEM Code: PHAS2117
Term: 2
Pre-requisites: PHAS1245 Mathematics 1
PHAS1102 Physics of the Universe
Structure: 30 lectures, 3 hours of problem classes/discussion

The course covers basic requirements, central principles, and practical considerations for components used in complete astronomical data-acquisition systems in different wavebands in the electromagnetic spectrum. These general concepts are discussed with regard to telescopes, spectrometers and detector-systems. Examples of working systems are discussed.
Topics:
Origin of the Solar System, dynamics and composition. Basic structure of the Sun in terms of the physics of energy transport from the core. Source of solar magnetic field, solar activity and sunspots. The solar wind and the interplanetary magnetic field. The interaction of the solar wind with solar system bodies..Planetary magnetospheres, radiation belts, charged particle motions in a planetary magnetic field. Internal structure of the Terrestrial Planets. Interior and surface evolution. Observational methods, in particular seismic studies on Earth. Gravitational potential and tidal forces. Roche limit. Instability limit. Relevance to why rings surround the Gas Giants. Thermal structure and atmospheres of planets. The Gas Giants. Physics of hydrogen under great pressure. Asteroids and meteorites, Comets, the Oort Cloud and the Kuiper belt

MATHEMATICAL METHODS III Code: PHAS2246
Term: 1
Pre-requisites: PHAS1245 , PHAS1246
Structure: 33 lectures, 11 hours of problem classes/discussion

Together with the two first year mathematics courses, PHAS2246 will provide the necessary mathematical underpinning for all core Physics and Astronomy modules throughout the BSc/MSci programmes. Completion of PHAS1245 and preferably PHAS1246 will normally be required for entry onto the course. Completion of the course and proven performance in its continuous assessment will be the norm for students wishing to proceed to the second semester mathematics half-unit MATHS6202 provided for second year Physics & Astronomy students.

Topics:

Linear Vector Space, Determinants and Matrices. Partial Differential Equations. Legendre Functions. Fourier Analysis. Group Theory.

QUANTUM PHYSICS **Code: PHAS2222**

Term: **1**

Pre-requisites: **PHAS2246 Maths III (this may be taken in parallel) or its equivalents**

Structure: **27 lectures, 6 hours of problem classes/discussion**

This is an introductory core course in quantum mechanics covering the failure of classical Newtonian mechanics and the basics of quantum mechanics motivated by physical examples. It aims to develop an understanding of the principles of Quantum Mechanics and their implications to the solution of physical problems. It forms the essential basis for many of the succeeding courses within Physics and Astronomy.

Topics:

The failure of classical physics. Steps towards wave mechanics. One-dimensional time-independent problems. The formal basis of quantum mechanics. Angular Momentum in quantum mechanics. The hydrogen atom - qualitative treatment. Magnetic moments and electron spin. Correspondence principle and Expansion Postulate. Ehrenfest's theorem. Introduction to atomic structure Review of one electron atoms. Many-electron atoms including the Pauli Principle and spin. Atoms and radiation. Atoms in static electric and magnetic fields. Molecular Structure and bonding. Molecular Spectra. Harmonic oscillator.

ATOMIC AND MOLECULAR PHYSICS **Code: PHAS2224**

Term: **2**

Pre-requisites: **PHAS2201 Electricity and Magnetism and**
PHAS2222 Quantum Physics or their equivalents

Structure: **27 lectures, 6 hours of problem classes/discussion**

This course introduces the physics of atoms and molecules which has established the quantised nature of physical phenomena. A core course which builds on the observations and ideas of the preceding courses in electromagnetism and quantum physics to enable the student to understand the structure and spectra of simple atoms and molecules, and to develop such understanding to a point where problems can be tackled. The course provides the basis for many further courses in the Department, not only in atomic and molecular physics, but also nuclear physics, modern optics, plasma physics and many branches of astrophysics.

Topics:

Introduction to atomic structure. Review of one electron atoms. Many-electron atoms including the Pauli Principle and spin. Atoms and radiation. Atoms in static electric and magnetic fields. Molecular Structure and bonding. Molecular Spectra.

ENVIRONMENTAL PHYSICS **Code: PHAS2427**

Term: **2**

Pre-requisites: **PHAS1228 Thermal Physics, PHAS1247 Classical Mechanics**

Structure: **27 lectures, 6 hours of problem classes/discussion**

An optional course which enables the student to understand the structure and dynamics of the Earth’s atmosphere and oceans. Topical issues such as global warming, ozone depletion and acid rain will be discussed. This course will provide a link between the pure physics and applied physics degrees and be pertinent to the Physics with Space Science degree.

Topics:

Radiation; Spectrum of Solar radiation; Energy transfer; Structure and composition of the atmosphere; Fluid dynamic; atmospheric circulation; Energy resources; power consumption; pollution.

STATISTICAL THERMODYNAMICS **Code: PHAS2228**

Term: **2**

Pre-requisites:

Structure: **27 lectures, 6 hours of problem classes/discussion**

The course aims to establish a secure structural foundation to an understanding of statistical thermodynamics that is essential to the study of processes at the microscopic level and of solid-state physics.

Topics:

Introduction. Principles of Statistical Physics. Isolated systems. Systems in contact with a heat bath. Classical gases. Ideal quantum gases. Bose-Einsten statistics. Fermi-Dirac statistics.

PRACTICAL ASTROPHYSICS 2A **Code: PHAS2130**

Term: **1**

Pre-requisites:

Structure: **72 hours of practical work split between a lab and a computer cluster**

This course provides an introduction to the basic specialist skills required by the practicing astrophysicist through a range of experiments in Laboratory Astrophysics including an introduction to Mathematica.

Topics:

A selection of 2nd Year level scripted experiments designed for Astrophysics students: a short course on the basic techniques required for numerical analysis of theoretical results and their comparison with experimental data, with emphasis on the use of various computer packages. Introduction to the Mathematica programming language.

PRACTICAL PHYSICS 2A **Code: PHAS2440**

Term: **1**

Pre-requisites:

Structure: **72 hours of practical work**

The course provides an introduction to the basic specialist skills required of the practicing physicist by means of a range of experiments in Physics including an introduction to Numerical Methods.

Topics:

A selection of 2nd year level scripted experiments designed for Physics students, a short course on the basic techniques required for numerical analysis of theoretical results and their comparison with experimental data, with emphasis on the use of various computer packages. Basic electronic techniques are also introduced and developed by providing practise in design and construction of a circuit including diagnosis and rectification of faults.

PRACTICAL PHYSICS 2B **Code: PHAS2441**

Term: **2**

Pre-requisites:
Structure: **72 hours of practical work split between a lab and a computer cluster**
This course includes a Physics project together with a course of instruction in computer based skills in particular the Mathematica programming language. It aims to provide instruction in some of the more advanced specialist skills required of a practising Physicist and an opportunity to use the skills acquired in project work.

PRACTICAL PHYSICS 2C **Code: PHAS2442**
Term: **2**
Pre-requisites:
Structure: **72 hours of practical work split between a lab and a computer cluster**
This course involves experiments in Laboratory astrophysics/physics including an introduction to the Mathematica programming language.
Topics:
A selection of advanced 2nd Year level scripted experiments designed for Physics with Space Science students. The use of word processors to prepare reports is encouraged. Mathematica programming language is introduced.

ELECTRICITY AND MAGNETISM **Code: PHAS2201**
Term: **1**
Pre-requisites: **PHAS1245 Maths I and PHAS1246 Maths II**
Structure: **27 lectures, 6 hours of problem classes/discussion**

This is the foundation course in electricity and magnetism to be taken by all undergraduates. It provides the basis for advanced courses in electricity and magnetism and essential techniques for use in other areas of physics.
Topics:
Milestones in electromagnetism. Electrostatics. Conductors. Dielectrics. DC circuits. Magnetostatics Electromagnetic induction. AC circuits. Maxwell's equations

PRACTICAL MATHEMATICS 2 **Code: PHAS2443**
Term: **1**
Pre-requisites: **PHAS1449**
Structure: **11 lectures/demonstrations, 72 hours of practical work**
The Mathematica component of this module equips students with the ability to analyze and solve problems of mathematical physics within a modern computing environment. It establishes a bridge between the mathematics and computer programming which are taught elsewhere in the course, and illustrates the benefit of computer packages for problem analysis, for problem solving, and for displaying results. **This module is intended for students following the Theoretical Physics degree course.**

The mini project increases a student's ability and confidence to undertake scientific investigation without the need for prescriptive instruction and to present the results in a written report.

SPACE SCIENCE, INSTRUMENTATION AND TECHNIQUES **Code: PHAS2665**
Term: **2**
Pre-requisites: **PHAS1664**
Basic knowledge of mechanics, electromagnetism and astronomical concepts
Structure: **27 lectures, 6 hours of problem classes/discussion**

The course can be roughly divided into three parts: an introduction to space astronomy, a quantitative description of the analysis techniques used in space and a quantitative account of the instruments and techniques used in remote sensing of the Earth.

Topics:

Description of the physics and operation of the photon detectors most commonly used (photo-emissive, photo-conductive and gas-filled); this is complemented by a description of their practical application in X-ray astronomy satellites, past, present and planned, and by an overview of the scientific knowledge that has been gained with their use. Analysis techniques used in space to establish the energy and mass of plasma particles, charged and neutral; and how these techniques have been applied to gather information on the Earth's magnetosphere, the solar wind and its interaction with the Earth's and other planets' magnetosphere, and with other bodies in the solar system, such as comets. The basic physics principles in remote sensing, examples of applications of such techniques to specific issues concerning the Earth's surface and its climate.

MEDICAL RADIATION PHYSICS Code: PHAS2881

Term: **2**

Pre-requisites: **Students normally from the Medical Physics stream**

Structure: **28 lectures, 20 hours of written work (essays), 6 hours of problem classes/discussion**

This introductory course provides a sound basic knowledge and understanding of various uses of ionising and non-ionising radiations for diagnosis and imaging in Medical Physics. It imparts sufficient knowledge to provide a basis for further courses in more specialised applications and core knowledge for career work within these fields.

Topics:

Theoretical principles of ionising radiation sources; interactions in materials; dosimetry and clinical applications; theoretical principles of ultrasound production, its propagation in materials and methods of detection; theoretical basis of NMR signal and its detection; introduction to the principles of light interaction with tissue, light transport and distribution as a function of the tissues.

MATHEMATICS FOR PHYSICS AND ASTRONOMY Code: MATH6202

Term: **2**

Pre-requisites: **PHAS2246 Maths 3**

Structure: **3 hours lectures and 1 hour problem class per week.**
Weekly assessed coursework.

This is a course of advanced mathematical methods for students of Physics and Astronomy who intend to proceed further with theoretical studies. It forms a natural pre-requisite of the 3rd Year course PHAS3423 Methods of Mathematical Physics.

Topics:

Functions of a complex variable: power series, elementary functions, branch points and cuts, continuity and differentiability, analytic functions, Cauchy-Riemann equations, harmonic functions, singularities, Taylor and Laurent series, Cauchy's integral formula.

Calculus of variations: Euler's equation, simple examples, problems with integral constraints, approximate solutions.

Analytical Dynamics: mechanical systems, Hamilton's principle, Lagrange's equations,
Hamilton's equations, constants of the motion, phase space.

DEVELOPING EFFECTIVE COMMUNICATION 2 Code: PHAS2901

Term: **1&2**

Pre-requisites: **PHAS1901**

Aim of the Course:
This is the second of three modules that aim to develop your skills in getting your message across, and in understanding the messages of others. These skills are crucial not only for being an effective physicist, but also in functioning effectively in many career – or non-career – situations.

Objectives:
After completing this module successfully, students should be able to:

- write medium-length pieces for non-specialist and specialist audiences;
- produce short briefs on scientific issues for a lay audience;
- orally present scientific ideas to a medium-sized group of peers using full visual aids;
- summarize scientific ideas succinctly and accurately;
- appreciate some of the ethical implications of being a scientist;
- present and defend ideas using a poster presentation;
- maintain a personal web page;
- use appropriate IT effectively.

3rd Year Courses

(All courses are of half-unit value unless stated otherwise)

PHYSICS PROJECT - BSc **Code: PHAS3400**
Value: **One unit**
Term: **1 and 2**
Pre-requisites:
Structure: **180 hours of independent project work**

This course stimulates an anticipation of research and work in a problem-solving environment. It enables students, who work independently or in pairs, to tackle novel and stimulating problems drawn from many areas of Physics, and related disciplines, both theoretical and experimental. The course aims to develop a student's confidence and ability and to work independently to solve problems, posed here in a research-type context. It inculcates the keeping of clear records of progress in a logbook and emphasises communication skills via written and oral reports presented during, and at the end of, the course. It builds upon the largely prescriptive experimental work encountered in the practical skills units of the first two years and enhances the communication skills developed in these years.

METHODS OF MATHEMATICAL PHYSICS **Code: PHAS3423**
Term: **1**
Pre-requisites: **MATH6202**
Structure: **30 lectures, 3 hours of problem classes/discussion**

This course offers an introduction to the modern theory of dynamical systems with applications in Physics and their relevance to modelling mechanical and physical systems.
Topics:
Continuous dynamical systems: Hamiltonian systems, Liouvilles's theorem, dissipative systems, local stability analysis, non-linear oscillators, bifurcation analysis in one and two dimensions. Discrete dynamical systems: Iterated maps, logistic map, cycles and stability, period doubling, bifurcations, Lyapunov exponents. Stochastic processes, Brownian motion, stochastic calculus.

ELECTROMAGNETIC THEORY **Code: PHAS3201**
Term: **1**
Pre-requisites: **PHAS2201, PHAS 1245, PHAS1246, PHAS2246**
Structure: **27 lectures, 6 hours of problem classes/discussion**

This course will build on PHAS2201 to establish Maxwell's equations of electromagnetism and use them to derive electromagnetic wave equations and an understanding of e-m wave propagation in different media. They will be used to help understand energy flow in the waves and the optical phenomena of reflection, refraction and polarization.
Topics:
Dielectric media, magnetic fields, linear magnetic media, ferromagnetism, Maxwell equations and e.m waves, reflection and refraction at a plane dielectric surface, energy flow and the Poynting vector, waves in conducting media, Emission of radiation, Hertzian dipole, relativistic transformations of e.m. fields.

NUCLEAR AND PARTICLE PHYSICS **Code: PHAS3224**

Term: **2**
Pre-requisites: **PHAS2224 Atomic and Molecular Physics**
also PHAS2222
Structure: **30 lectures, 3 hours of problem classes/discussion**

This is a core course which introduces nuclei and particles. It outlines their systematics and explores the nature of the forces between them. Although self-contained the course provides the groundwork for fourth year courses in nuclear and particle physics.

Topics:
Introduction to the Standard Model. The relationship between the theory and the measurables. Interaction Kinematics. Feynman Diagrams. Experimental Issues of Particle Physics. Introduction to composite particles (Hadrons and Baryons). Cross-section and lifetime: measurables. The weak interaction. Accelerators and detectors. Introduction to nuclear physics. Liquid drop model and the Semi-empirical mass formula. Fission and fusion. Resonance enhanced neutron capture for waste transmutation. The nuclear shell model.

SOLID STATE PHYSICS **Code: PHAS3225**

Term: **2**
Pre-requisites:
Structure: **30 lectures, 3 hours of problem classes/discussion**

The course aims to lay a secure foundation for the understanding of the underlying principles of the structure of the solids, determination of their structures (and defects therein), and to establish an understanding of the relationship between structure and their thermal, mechanical, electronic and magnetic properties. The basis allows further advanced development in 4th year MSci modules.

Topics:
Review of bonding and structure in solids; covalent, molecular, ionic, metallic, hydrogen bonding. Crystalline and non-crystalline materials. Principles of (x-ray & neutron) structure determination of solids; direct and reciprocal lattices, Laue condition. Mechanical properties of solids; elasticity, dislocations, strength of materials (crystalline and non-crystalline). Lattices in motion; phonons, dispersion curves, heat capacity, Einstein and Debye models, thermal conductivity. Electrons in solids; simple models of conduction, Hall effect, heat capacity, basic band theory, Fermi surface, insulators, metals, and semiconductors. Pure and doped semiconductors and simple semiconducting devices. Optical properties of solids, dielectric constant, refractive index.

QUANTUM MECHANICS **Code: PHAS3226**

Term: **1**
Pre-requisites: **PHAS2222**
Structure: **30 lectures, 3 hours of problem classes/discussion**

This is a core course which builds on a previous first course in Quantum Mechanics. It aims to extend the students' knowledge base and to give a deeper understanding of the subject. The course material is essential for many courses offered in the MSci year.

Topics:
A summary of the basic concepts and postulates of quantum mechanics. Dirac Notation: Linear harmomic oscillator by operator techniques.
Theory of orbital, spin and generalised angular momentum, with an introduction to coupling of two angular momenta. Applications and approximations; the hydrogen-like ion: full treatment; time-independent, non-degenerate perturbation theory up to second order; first-order degenerate perturbation theory. Time evolution of simple systems with a time-independent Hamiltonian. Systems of identical particles; Pauli principle, bosons and fermions.

PRACTICAL ASTRONOMY 1 - TECHNIQUE **Code: PHAS3330**
Term: **1**
Pre-requisites: **PHAS1130, and PHAS2130**
Structure: **1 lecture, 64 hours of practical work**

The aim of the course is to develop competence in planning a set of astronomical observations, using large telescopes, CCD detectors and spectroscopy, and applying a range of data reduction techniques. The course content will comprise the use of data compilations to plan a set of imaging observations (Radcliffe 24”/18” Long Focus Refractor) and a set of spectroscopic observations (Allen 24” Reflector); data reduction procedures in positional astronomy (including radial velocity measurements); data reduction procedures in astronomical spectroscopy (stars, extended objects) and data reduction procedures for photometry. An introductory lecture is presented in Gower Street, after which each student is expected to attend the Observatory on one afternoon and evening per week.

During the first 5 weeks of the course the use of the telescopes, computers and other equipment is taught. During the remainder of the course the emphasis switches to the completion of two longer and more detailed experiments. Observing with the telescopes continues throughout the course, making maximum use of available clear weather.

PRACTICAL ASTRONOMY 2 - APPLICATIONS **Code: PHAS3331**
Term: **2**
Pre-requisites: **PHAS3330 Practical Astronomy 1 - Technique**
Note: Students undertaking PHAS3331 do not take PHAS3332.
Structure: **62 hours of practical work**

The aim of this course is to develop competence in the use of telescopes by extending the observational programmes of PHAS3330 and in the application of data reduction techniques to astrophysical data sets and in the analysis of such reduced sets to derive astrophysically relevant information. The course content will be in the form of mini-projects on positional astronomy (e.g. derivation of the elements of a comet or asteroid), astronomical spectroscopy of stars - both normal and peculiar, extended objects, galaxies and interstellar matter.

PRACTICAL ASTRONOMY 3 - FIELD TRIP **Code: PHAS3332**
Term: **2**
Pre-requisites: **Successful completion of PHAS3330**
Please note: This Field Trip is only open to the best qualified 10 - 12 students taking course PHAS330.
Note: Students undertaking PHAS3332 do not take PHAS3331
Structure: **60 hours of Field Work, 8 hours of preparation work to be carried out at ULO**

The aim of the course is to give selected students hands-on experience of developing and executing a programme of spectroscopy and CCD photometric observations at a mountain site of high quality overseas.
The operation of this course depends upon the award of observing time to an observing proposal submitted to a host observatory by the course organiser.
The course takes place during the Spring Term. Each student is expected to attend the ULO on 4 or 5 evenings for orientation sessions. Approximately one week is then spent observing in the field at the host observatory, currently the Observatoire De Haute Provence in Southern France, followed by more sessions at ULO to complete data reduction and analysis.

INTERSTELLAR PHYSICS **Code: PHAS3333**
Term: **2**
Pre-requisites:
Structure: **30 lectures, 3 hours of problem classes/discussion**

The aim is to teach the basic physics of the interstellar gas in its diffuse, ionised, and molecular phases, together with the properties of interstellar dust.

Topics:
Applications of radiative transfer, energy balance, and line-formation mechanisms as diagnostics of the physics and chemistry of the interstellar medium (ISM). Detailed attention is paid to interstellar gas dynamics and shocks. The structure and evolution of photoionised nebulae are derived, and the earliest stages of star formation are discussed. Free-free continuum emission and Line formation in the diffuse ISM is considered in detail. The formation and destruction of dust grains is reviewed, together with the basic principles underlying the extinction which they produce. Simple reaction networks and rate equations are developed for astrochemical molecular processes, and are put into context.

THE PHYSICS AND EVOLUTION OF STARS **Code: PHAS3134**
Term: **1**
Pre-requisites: **PHAS2112 - Astrophysical Processes**
PHAS2228 - Statistical Thermodynamics
Structure: **30 lectures, 3 hours problem classes/discussion**

This is a course dealing with the theory of radiative transfer and the structure of stellar atmospheres and interiors, and the use of these to understand the formation, evolution and death of stars. It builds on the basic astrophysical concepts and processes that were introduced in the 2nd Year. It is the core course in stellar astrophysics, and is a pre-requisite for the 4th Year course on Advanced Topics in Stellar Astrophysics and Evolution .
Topics:
Equations of Stellar structure. Stellar Atmospheres and radiative transfer. Radiative opacities. Convection in stars. Basic stellar structure models. Evolution onto the Main-Sequence. Post Main-Sequence Evolution.

COSMOLOGY AND EXTRAGALACTIC ASTRONOMY **Code: PHAS3136**
Term: **2**
Pre-requisites: **PHAS2112 – Astrophysical Processes: Nebulae to Stars**
Structure: **30 lectures, 3 hours of problem classes/discussion**

This is an advanced course on the structure and evolution of the Universe, galaxies, quasars and related objects, and how they are studied from an observational point of view. The aim is to enhance the students' knowledge and understanding of these topics and their relationships.
Topics:
Cosmology: Cosmological models; the microwave background; primordial nucleosynthesis; inflation; the cosmological constant; large-scale structure.
Galaxies: Morphology; chemical, physical, and dynamical structure; clusters of galaxies. Dark matter in galaxies and clusters of galaxies.
Active Galactic Nuclei: Taxonomy; characteristics of the central engine; reverberation mapping; quasar absorption-line systems; the quasar luminosity function; the evolution of galaxies and the star-formation history of the Universe.

ASTRONOMICAL SPECTROSCOPY **Code: PHAS3338**
Term: **1**
Pre-requisites: **PHAS2222 - Quantum Physics**
Structure: **30 lectures, 3 hours problem classes/discussion**

This is a course developing an understanding of the spectra of atoms and molecules and their uses in astronomy. Wherever possible, the discussion will be illustrated by real astronomical spectra.
Topics:
Spectral lines observed from astronomical objects and their interpretation. The structure and radiative properties of atoms and molecules. Pauli's principle and electron shells; angular momentum; fine structure; hyperfine structure; radiation in spectral lines; forbidden transitions; atoms in external fields; molecular rotational, vibrational and electronic structure and transitions. Spectroscopy of stars, interstellar matter, galaxies, planets and other astronomical objects.

TECHNIQUES AND OPTICS IN MODERN ASTRONOMY **Code: PHAS3301**
Term: **2**
Pre-requisites: **PHAS1224 – Waves, Optics and Acoustics;**
PHAS2246 Mathematics III
Structure: **30 lectures, 3 hours problem classes/discussion**

This course will provide the necessary skills for a student to understand the design and operation of modern astronomical instruments.
Topics:
Optics Theory: Wave propagation theory, Imaging theory, Polarisation, Fourier Optics, Convolution/deconvolution. UV/Visible/NIR techniques: Telescope Design, Optical aberrations, Detectors, Imaging, Photometry, Signal to noise, Spectroscopy, Grating equation , Cross dispersion , Echelle spectrograph, Multiple object spectroscopy, Integral field units, Polarimetry, Adaptive Optics, Coronography, Optical Interferometry. Radio Astronomy techniques: Radio sources, Radio Receivers (Detectors, antenna), Heterodyne frequency shift, Spectroscopy, Radio dishes, Radio Interferometry. X-ray and Gamma-ray techniques: Sources, Detectors, Imaging high Energy Radiation, Spectroscopy at high energies, Bragg equation. Exotic Astronomy: Very High Energy (VHE) Gamma Rays, Sources of radiation, VHE Gamma ray Telescopes, Neutrino Astronomy, Neutrino production, Neutrino detectors, Gravity Wave Detectors, Sources, Detector systems.

EXPERIMENTAL PHYSICS **Code: PHAS3440**
Term: **1**
Pre-requisites: **PHAS1240 - Practical Skills 1C and**
PHAS2440 - Practical Physics 2A
Structure: **35 hours of practical work, 35 hours problem classes/discussion**

This course entails advanced experimentation in Physics and statistical analysis of data with a short introductory course in 'Mathematica'.

Topics:
One long experimental investigation lasting half a term involving the integration of several experimental techniques to complete the task. A short course, working from a programmed text, in statistical analysis of data. Training and practice in report writing. A short course lasting half a term in the use of symbolic manipulation techniques using the programme 'Mathematica' for the solution of mathematical problems and modeling.

GROUP PROJECT - PHYSICS **Code: PHAS3441**

Term: **2**

Pre-requisites:

Structure: **3 lectures, 77 hours of independent project work, 10 hours of written work (essays), 12 hours problem classes/discussion. Short interview.**

The course aims to teach students how to function effectively in a group situation stimulating the actual working environment they will encounter in the course of their professional careers. The technical skills exercised in the collective solution of the set problem rely on practical skills developed in courses in the first two years.

Topics:

Students take part in training in group interaction and management. They then practice these skills in small groups by attempting the solutions of a complex technical problem in physics which requires group co-operation for its solutions.

LASERS AND MODERN OPTICS **Code: PHAS3443**

Term: **2**

Pre-requisites: **PHAS1224 - Waves, Optics and Acoustics**

Structure: **30 lectures, 3 hours problem classes/discussion**

This course aims to give an introduction to modern optics and laser physics to ensure that the students are conversant with the principles of laser physics and are competent in applying them to different physical processes.

Topics:

Matrix optics. Laser principles. Gaussian optics. Electro-optics. Non-linear optics. Guided wave optics.

MATERIALS SCIENCE **Code: PHAS3446**

Term: **2**

Pre-requisites: **PHAS2228 - Statistical Thermodynamics and Condensed Matter Physics**

Structure: **30 lectures, 3 hours problem classes/discussion**

This course is an introduction to the physics of materials science which addresses the mechanical, electrical, magnetic and optical properties of manufactured materials, and the factors which lead to their exploitation in commercial devices. It is an optional course which builds on the core courses PHAS2228 and PHAS3225.

Topics:

Property relations for a variety of materials covering a range of complexity, including microstructures and mechanical properties, electrical, optical and magnetic properties, polymers, comparatives, bio-materials and advanced device materials.

SCIENTIFIC COMPUTING USING OBJECT ORIENTED LANGUAGES.

Code: PHAS3459

Term: **2**

Pre-requisites: **None: Previous experience of programming an advantage.**

Structure: **Two weekly 3-hour sessions for 11 weeks equally divided between instruction / Lectures and practice at the computer.**

The course aims to provide an introduction to the use of object oriented (OO) programming in the context of physics data handling and analysis using the JAVA language.

Topics:
Basic program control, OO concepts and design; implementation of JAVA programming tools; program design and application; principal differences between JAVA and C++.

PHYSICS OF THE EARTH **Code: PHAS3661**
Term: **1**
Pre-requisites:
Structure: **30 lectures, 3 hours problem classes/discussion**

This course is primarily an option for the Physics with Space Science degree. It has emphasis on the new insights provided by modern techniques, including seismic techniques for studying the Earth's interior, satellite altimetry for determining the geoid and ocean circulations, laser ranging and very long baseline interferometry for measuring continental drift.
Topics:
Mass and density of the Earth; Earth Gravity; Earth magnetism and plate tectonics; Earthquakes; seismology; origin of the Solar System; Earth's climate; Earth observation for geophysics and climate.

SPACE SYSTEMS TECHNOLOGY **Code: PHAS3664**
Term: **1**
Pre-requisites: **Students normally from the Physics with Space Science stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**

This course is an advanced survey of current space technology and techniques. It introduces students to spacecraft subsystems and techniques which must be implemented to overcome the rigorous constraints imposed on the spacecraft and payload by launch and orbit environments. The subject will be presented at a level suitable for those hoping to enter a professional career in an aerospace discipline.
Topics:
Subsystems of a typical scientific spacecraft; budgets, cost link, mass heat, power. Structure and materials, mechanical systems and testing, Power generation and control. Instrumentation and associated electronics. On-Board Data Handling. Spacecraft internal and external communications, signal modulation and encoding. Thermal control, altitude control, stabilisation and measurement, attitude dynamics of rigid bodies in terms of angular momentum, the inertia tensor, principle moments and principal axes. Attitude sensors. The effects of non-rigidity. The rocket equation revisited, propulsion and thrusters for orbital applications. The ion thruster.

MEDICAL SCIENTIFIC COMPUTING **Code: COMP3053**
Term: **2**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**
Note: Given by Computer Science Department

The course provides information on the use of computers for processing, in particular, pictorial information in the medical domain, for example Computerised Tomography and Nuclear Magnetic Resonance.
Topics:
Data handling; basic mathematical tools; principles and clinical applications of tomographic method; data display; picture archiving and communication systems (PACS); the man-machine interface; some clinical problems.

MEDICAL IMAGING WITH IONISING RADIATION **Code: PHAS3890**

Term: **1**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**

The aim is for the students to understand the use and application of techniques and methods of imaging both anatomy and physiological function using ionising radiation, including processing evaluation of their performance and the principles of quality assurance.

Topics:

Sources of Ionising Radiation; Interaction in the patient; different detectors; systems; the use of systems; image processing and assessment; quality control.

MEDICAL IMAGING WITH NON-IONISING RADIATION **Code: PHAS3891**

Term: **1**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course will provide a basic introduction to the physical principles of NMR and ultrasound and their application to the imaging of both anatomy and physiological function. The methods by which images of anatomy and function are obtained are explained as well as their applications in medicine.

Topics:

Basic NMR theory; NMR signal acquisition; NMR hardware; Tissue parameters and contrast in imaging; data acquisition and image formation; image processing; NMR safety; ultrasound imaging; transducers; ultrasound beams; safety considerations; resolution; scanner construction, signal processing; artefacts and measurements; the Doppler effect; tissue characterisation; therapeutic applications.

TREATMENT USING IONISING RADIATION **Code: PHAS3892**

Term: **2**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course covers theory and methods of treatment using ionising radiation, including dosimetry, radiobiology and protection.

Topics:

Dosimetry; radiobiological basis; dose distribution and radiotherapy treatments; radiation protection.

PHYSIOLOGICAL MONITORING **Code: ELEC3009**

Term: **2**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**
Note: Course supplied by the Electronic and Electrical Engineering Dept.

The course provides an understanding of the theory and practice of transducers and monitoring techniques in medicine and physiology. It covers most of the commonly used methods in medical practice except those derived from imaging and radionuclide methods.

Topics:

Measurement variables; Pressure, force and position sensing; Piezoelectric sensors; Temperature sensing; Flow, velocity and volume sensors; Optical sensors; Gas and ion sensors.

MATHS FOR GENERAL RELATIVITY **Code: MATH3305**

Term: **1**

Pre-requisites: **MATH6202 (Physicists and Astronomers);**
MATH2303 (Mathematicians)

Structure: **3 hour lectures per week**

This course is available to 3rd or 4th year students with a good mathematical ability.

The course introduces Einstein's theories of special and general relativity. Special relativity shows how measurements of physical quantities such as time and space can depend on an observer's frame of reference. Relativity also emphasises that there exists an underlying physical description independent of observers. This physical description uses mathematical objects called tensors. Tensor notation simplifies the form of the Maxwell equations and reveals their power and beauty. The Maxwell equations provide a description of electromagnetism compatible with special relativity. However, no similar equations exist for gravitation. Instead, a more general form of relativity is needed where space-time has curvature. Curvature, in effect, replaces the gravitational field. Objects no longer accelerate due to gravitational forces; instead they move along geodesics whose shape is determined by the curvature. Furthermore, rather than mass being the source of the gravitational field, a massive object warps the space around it, generating curvature.

COSMOLOGY **Code: MATH3306**

Term: **2**

Pre-requisites: **MATH3305 - Mathematics for General Relativity**

Structure: **3 hour lectures per week**

This course is available to 3rd or 4th year students with a good mathematical ability.

Cosmology is the study of the history and structure of the Universe. Cosmologists usually assume that the Universe is highly symmetric on large scales; under this assumption the equations of general relativity reduce to two simple ordinary differential equations. These equations govern the expansion of the Universe. These equations are studied in detail, and show how observations are affected by the expansion and curvature of the Universe. The course then covers the astronomical methods used to determine the expansion rate (i.e. the Hubble constant) and the mass density of the Universe. Physical processes in the early universe such as nucleo-synthesis, the formation of the microwave background, and galaxy formation will also be studied. The course begins with a description of black holes and ends with speculative topics including inflation and cosmic strings.

ASTROBIOLOGY **Code: GEOL3027**

Term: **2**

Pre-requisites: **There are no formal prerequisites.**

Aims and Objectives

This course is designed to provide a broad introduction to the exciting new field of astrobiology -- the study of the astronomical and planetary context within which life on Earth has evolved, and the implications for the prevalence of life elsewhere in the Universe. The course will be suitable for a diverse audience of undergraduate students in their second year or above, and who pursuing degrees in Planetary Science, Earth Sciences, Physical Sciences, and Astronomy/Astrophysics.

Topics:

Origin and distribution of biologically important chemical elements. Origin and early evolution of the Solar System and implications for other planetary systems. Pre-biological chemical evolution and the origin of life. Summary of evolutionary biology (3 lectures). Rare Earth? Requirements for life. Prospects for life eleswhere in the Solar System. Extrasolar planets. Extraterrestrial intelligence.

4th Year Courses

(All courses are of half-unit value unless stated otherwise)

MSci PHYSICS PROJECT **Code: PHAS4201**
Value: **1.5 Units**
Term: **1 & 2**
Pre-requisites: **1st , 2nd and 3rd year practical courses to have been successfully taken**
Structure: **200 hours of independent project work, 30 hours of written work**

The course aims to develop a student’s confidence and ability to work as an independent researcher and inculcates the keeping of clear records in a progress log. It builds on the largely proscriptive experimental work encountered in the practical skills units of the first three years plus the smaller components of group and individual project work. An emphasis on good communication via written and oral reports continues the stress laid on this in the first three years. Students work independently or in pairs (depending on the scope of the project) on a major investigation which may be experimental, theoretical or involve computer simulation. Students are required to keep a detailed log of their day to day work and present their findings in a final written report plus an oral presentation. The final report is expected to be presented in a fully word processed form.

MSci ASTRONOMY PROJECT **Code: PHAS4101**
Value: **1.5 Units**
Term: **1 & 2**
Pre-requisites:
Structure: **200 hours of independent project work, 30 hours of written work**

The aim of the course is to enable the student to undertake real scientific research for the first time. Students will build on the formal knowledge and practical techniques that they have acquired from lectures and practicals during the preceding three years. Students will have their own supervisor who will be a staff member (or senior contract research staff person). A 1 unit course consisting of a research project over 2 semesters, in any area related to astronomy and astrophysics. The project can be any combination of theory, analysis, observation, instrumentation or history and philosophy of astronomy, provided the work is original. Students will provide an extended written report (dissertation) which as well as describing the results of their research, should contain a review of previous related work. Students will also give a 15-minute oral presentation, using audio visual aids, on the results of their project.

ADVANCED QUANTUM THEORY **Code: PHAS4426**
Term: **1**
Pre-requisites: **3226 or equivalent.**
Structure: **30 lectures, 3 hours problem classes/discussion**

This is a course where some aspects of the basic postulates of quantum mechanics are discussed more formally and mathematically than in earlier courses. The course extends perturbation theory to time-dependent systems and gives students an introduction to a quantum mechanical description of the scattering of low-energy particles by a potential - two important topics for other fourth-year courses.

Topics:
An algebraic operator approach for angular momentum, both orbital and spin; the addition of angular momenta. The variational method for non-perturbative approximations and the JWKB

approximation. Time-dependent perturbation theory leading to Fermi's Golden Rule and applications to simple systems such as an harmonic perturbation. The quantum mechanical description of the scattering of low-energy spinless particles from a potential via the partial wave expansion and phase shifts. The first Born approximation.

PLANETARY ATMOSPHERES **Code: PHAS4312**
Term: **1**
Pre-requisites:
Structure: **30 lectures, 3 hours problem classes/discussion**

This course compares the atmospheres of all the planets and examines the past, present and future of the Earth’s atmosphere with the perspective offered by the comparison.
Topics:
Comparison of planetary atmospheres including; atmospheric structure, retention; oxygen chemistry; atmospheric temperature profiles; origin and evolution of planetary atmospheres; atmospheric dynamics; ionospheres; magnetospheres; observational techniques and global warming.

SOLAR PHYSICS **Code: PHAS4314**
Term: **2**
Pre-requisites:
Structure: **30 lectures, 3 hours problem classes/discussion**

The aim of this course is to present a detailed description of the structure and behaviour of the Sun and its atmosphere and to give the student a good understanding of the underlying physical processes.
Topics:
The Solar interior and photosphere; Solar magnetic fields; Solar activity; the Solar atmosphere - Chromosphere; the Solar atmosphere - Corona and Solar wind; Solar flares.

HIGH ENERGY ASTROPHYSICS **Code: PHAS4315**
Term: **2**
Pre-requisites:
Structure: **30 lectures, 3 hours problem classes/discussion**

This course provides an understanding of the theoretical processes responsible for a range of high-energy stellar and galactic sources, using observational data from Earth satellites.
Topics:
A simple introduction to General Relativity, by approaching the Schwarzschild and Kerr metrics from practical considerations rather than using highly mathematical tools;
A simple mathematical account of the mechanisms that lead to the production and absorption of high energy photons in the Universe; A quantitative account of cosmic sources of high energy radiation.

ADVANCED TOPICS IN STELLAR ATMOSPHERES AND EVOLUTION.
Code: PHAS4316
Term: **1**
Pre-requisites: **PHAS3134 - Physics and Evolution of Stars**
Structure: **30 lectures, 3 hours problem classes/discussion**

A course which develops the theory of model atmosphere techniques and their application to quantitative analyses of stellar spectra; the effects of mass loss on the evolution of both high and low mass stars, and interaction effects in binary systems.

Topics:
The LTE Model Atmosphere: the formation of continua and spectral lines. Comparison of LTE model atmospheres with observations. The Non-LTE Model Atmosphere: two-level and multi-level atoms. Comparison of non-LTE model atmospheres with observations. Observations of stellar winds from hot stars and determination of mass-loss rates. The theory of line-driven stellar winds. The effects of mass-loss on stellar evolution for high and low mass stars. The evolution of massive close binary systems.

GALAXY AND CLUSTER DYNAMICS **Code: PHAS4317**
Term: **1**
Pre-requisites: **PHAS3136 - Cosmology and Extragalactic Astronomy**
Structure: **30 lectures, 3 hours problem classes/discussion**

This course provides an in-depth study of the dynamical structure and evolution of galaxies (elliptical and spiral), clusters within galaxies (open and globular), and clusters of galaxies. The course explains the origins and mechanisms by which galaxies and clusters have obtained their observed characteristics.
Topics:
Galaxies, Clusters, and the Foundations of Stellar Dynamics, Rotating Galaxies and the Structure of the Milky Way, Stellar Encounters and Galactic Evolution, Star Clusters, Elliptical Galaxies, and Clusters of Galaxies.

ATOM AND PHOTON PHYSICS **Code: PHAS4421**
Term: **1**
Pre-requisites:
Structure: **30 lectures, 3 hours problem classes/discussion**
The course introduces students to the interactions of photons with atoms. In particular the operation and use of lasers is discussed and the role of lasers in modern spectroscopic techniques.
Topics:
Interaction of light with atoms. L.A.S.E.R. Chaotic light and coherence. Laser spectroscopy. Multiphoton processes. Light scattering by atoms. Electron scattering by atoms. Coherence and cavity effects in atoms. Trapping and cooling.

QUANTUM COMPUTATION AND COMMUNICATION **Code: PHAS4427**
Term: **2**
Pre-requisites: **PHAS3226 or equivalent**
Structure: **30 lectures, 3 hours problem classes/discussion**
The course aims to provide a comprehensive introduction to the emerging field of quantum information (the basic notions such as quantum cryptography, quantum algorithms, teleportation and the like, as well as state of the art experiments), so that the student is well prepared for research (both academic and industrial) in the area.
***Topics**:*
Background: The qubit and its physical realization; Single qubit operations and measurements; The Deutsch algorithm; Quantum no-cloning. Quantum Cryptography: The BB84 quantum key distribution protocol; elementary discussion of security; physical implementations of kilometers. Quantum Entanglement: State space of two qubits; Entangled states; Bell’s inequality; Entanglement based cryptography; Quantum Dense Coding; Quantum Teleportation; Entanglement Swapping; Polarization entangled photons & implementations; von-Neumann entropy; Quantification of pure state entanglement. Quantum Computation: Tensor product structure of the state space of many qubits; Discussion of the power of quantum computers; The Deutsch-Jozsa algorithm; Quantum simulations; Quantum logic gates and circuits; Universal quantum gates;

Quantum Fourier Transform; Phase Estimation; Shor's algorithm; Grover's algorithm. Decoherence & Quantum Error Correction: Decoherence; Errors in quantum computation & communication; Quantum error correcting codes; Elementary discussion of entanglement concentration & distillation. Physical Realization of Quantum Computers: Ion trap quantum computers; Solid state implementations (Kane proposal as an example); NMR quantum computer.

MOLECULAR PHYSICS **Code: PHAS4431**
Term: **2**
Pre-requisites: **Quantum Physics (such as UCL course PHAS2222)**
Atomic Physics (such as UCL courses PHAS2224 or PHAS3338)

Structure: **30 lectures, 3 hours problem classes/discussion**

The course aims to introduce fourth year students to a detailed discussion of the spectroscopy and electronic states of polyatomic molecules.

Topics:

Molecular structure: Born-Oppenheimer approximation; Electronic structure ionic and covalent bonding, H_2, H_2^+; Vibrational and rotational structure.
Molecular spectra: Microwave, infrared and optical spectra of molecules; Selection rules, Experimental set-ups and examples; Raman spectroscopy. Ortho-para states.
Molecular processes: Collisions with electrons and heavy particles; Experimental techniques.

PARTICLE PHYSICS **Code: PHAS4442**
Term: **2**
Pre-requisites: **Basic Quantum, Atomic and Nuclear Physics**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course introduces the basic concepts of particle physics, including the fundamental interactions and particles and the role of symmetries. Emphasis will be placed upon how particle physics is actually carried out and the course will use data from currently running experiments to illustrate the underlying physics involved.

Topics:

Feynman diagrams as a tool for qualitative description of interactions. Relativistic wave equations. Conserved Current, Propagators and the Invariant Amplitude. Symmetries and conservation laws. Basic principles of calorimeters, drift chambers and silicon vertex detectors. QCD – confinement, asymptotic freedom and Jets. Deep Inelastic scattering, scaling and the quark parton model. Weak Interactions, the W and Z bosons. Quark and lepton doublets and Cabibbo mixing. Parity and C-Parity violation and handedness of neutrinos. Unification of weak and electromagnetic interactions. Neutrino oscillations and some other open questions.

SPACE PLASMA & MAGNETOSPHERIC PHYSICS **Code: PHAS4465**
Term: **2**
Pre-requisites: **PHAS3201. Also knowledge of vector algebra**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course introduces the student to the solar wind and its interaction with various bodies in the solar system, in particular discussing the case of the Earth and the environment in which most spacecraft operate.

Topics:

Introduction to magnetohydrodynamics, the solar wind, solar wind interaction with unmagnetised bodies, the solar wind interaction with magnetized bodies, various magnetospheric models, magnetic storms and substorms.

ORDER AND EXCITATIONS IN CONDENSED MATTER **Code: PHAS4472**
Term: **2**
Pre-requisites: **PHAS3225 – Solid State Physics**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course aims to provide a unified description of order and excitations in condensed matter with an emphasis on how they may be determined with modern x-ray and neutron techniques.

Topics:

Atomic Scale Structure of Material , Magnetism: Moments, Environments and Interactions, Order and Magnetic Structure, Scattering Theory, Excitations of Crystalline Materials, Magnetic Excitations, Excitations in ferromagnets and antiferromagnets, Magnons, Sources of X-rays and Neutrons (Full day visit to RAL.), Modern Spectroscopic Techniques, Phase transitions and Critical Phenomena, Local Order in Liquids and Amorphous Solids.

OPTICS IN MEDICINE **Code: PHAS4886**
Term: **1**
Pre-requisites: **Students normally from the Medical Physics stream.**
Structure: **30 lectures, 3 hours problem classes/discussion**

The course provides an introduction to the principles of optics and lasers in medicine, and the interaction of light with biological tissues. It gives a sound basic knowledge and understanding of the principles behind the various uses of light in diagnostic and therapeutic medicine and imparts sufficient knowledge to provide a basis for further courses in more specialised applications, and also forms the core knowledge for career work within these fields.

Topics:

Interaction of Light with Biological Materials; Sources of Light; Light delivery systems; Optical Sensors; Safety.

FOURTH YEAR INTERCOLLEGIATE MSci COURSES.

N.B. For full details, content etc., please refer to the MSci Handbook on the Web.

This list indicates taught courses of the fourth year of the Intercollegiate MSci degree programmes. Each course has a code number used by the Intercollegiate MSci board, shown at the left hand side. Colleges use local codes for the courses they teach. The *number* is usually the same as the MSci code, but some are different so beware! Local course codes are shown at the right hand side. All courses are a half course unit (in QMUL language, they are a full course unit). The list shows the course title and the term in which it is taught. Also indicated is the course teacher and the college supplying the course.

No.	Title	Term	Lecturer	College	Code
4211	Statistical Mechanics	2	Prof. B. Cowan	RHUL	PHAS4211
4226	Advanced Quantum Theory	1	Prof T. Monteiro	UCL	PHAS4426
4242	Relativistic waves and Quantum Fields	2	Dr. A. Brandhuber	QMUL	PHY899
4261	Electromagnetic Theory	2	Dr. W. J. Spence	QMUL	PHY966
4317	Galaxy and Cluster Dynamics	1	Prof M Cropper	UCL	PHAS4317
4421	Atom and Photon Physics	1	Prof. W. R. Newell	UCL	PHAS4421
4427	Quantum Computation and Communication	2	Dr. S. Bose	UCL	PHAS4427
4431	Molecular Physics	2	Dr A Bain	UCL	PHAS4431
4442	Particle Physics	2	Dr. M. Lancaster	UCL	PHAS4442
4472	Order & Excitations in Condensed Matter	2	Prof. D. McMorrow	UCL	PHAS4472
4473	Theory and treatment of Nano-systems	2	Dr. A. DeVita	KCL	CP4473
4474	Physics at the Nanoscale	1	Prof. G. Davies & Prof. V. Petrashov	KCL	CP4474
4478	Superfluids, Superconductors & Condensates.	1	Prof. J. Saunders	RHUL	PH4478
4512	Nuclear Magnetic Resonance	2	Prof. B. Cowan	RHUL*	PH4512
4515	Computing and statistical data analysis	1	Dr G. Cowan	RHUL*	PH4515
4600	Stellar structure and evolution	1$	Prof I. Williams	QMUL‡	ASTM109
4601	Advanced Cosmology	1	Dr. J. Lidsey	QMUL‡	ASTM108
4603	Astrophysical Fluid Dynamics	2	Dr.S.Vorontsov	QMUL‡	ASTM112
4630	Planetary Atmospheres	1	Dr I. Mason	UCL	PHAS4312
4640	Solar Physics	2	Dr I. Philips & Dr L. M van Driel-Gesztelyi	UCL	PHAS4314
4650	Solar System	2$	Dr J. Cho	QMUL‡	ASTM001
4660	The Galaxy	2$	Prof C. Murray	QMUL‡	ASTM002
4670	Astrophysical Plasmas	1$	Dr D. Burgess	QMUL‡	ASTM116
4680	Space Plasma & Magnetospheric Physics	2	Dr A. Coates & Dr C. Owen	UCL	PHAS4465
4750	Image Capture & Sensor Technology	2	Dr K. Powell	KCL	CP4750

4602	Relativity & Gravitation	2	Dr A. Polnarev	QMUL‡ MAS412

Students will undertake one or more project-related courses in accordance with practice at their own colleges.

‡ Taught by the *Mathematics* department of QMUL. [$] These QMUL courses are taught in the evenings.

* Courses taught at RHUL in Egham, although 4515 may be available over LiveNet at the UCL studio.