Masters in Physics

Taught Element:	A total of 120 credits from AS and PH modules at 4000 level and above, including at least 90 credits at 5000 level, the course of study to be approved by the Head of School.
MSc:	120 credits as for Taught Element together with a dissertation (PH5301) comprising 3 months full-time study and worth 60 credits.

Compulsory module for MSc - Summer

PH5301 Dissertation for MSc Programme				
SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	Summer
Availability restrictions:	Only available tos tudents on the Physics MSc Programme			
Planned timetable:	To be arranged.			
This dissertation will be supervised by a member of the academic staff who will advise on the choice of subject and provide guidance during the work. The completed dissertation of not more than 15,000 words must be submitted by the stated date in August.				
Programme module type:	Compulsory for MSc Physics Postgraduate Programme.			
Pre-requisite(s):	Successful completion of the first two semesters of the Physics MSc programme in the School.			
Learning and teaching methods and delivery:	**Weekly contact**: Weekly meetings with supervisor			
Assessment pattern:	Dissertation and Oral Examination = 100%			
Module Co-ordinator:	TBC			
Lecturer(s)/Tutor(s):	TBC			

Optional modules:

AS4010 Extragalactic Astronomy

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	12.00 noon Mon, Tue, Thu (TBC)			
This module introduces the basic elements of extragalactic astronomy. This includes the morphological, structural and spectral properties of elliptical, spiral, quiescent and star-forming galaxies. We study how galaxy populations change from the distant galaxies in the early Universe into those observed in our local neighbourhood, including the coincident growth of super massive black holes at the centres of massive galaxies. Galaxy formation theory is introduced in relation to the growth of structure in a cold-dark matter, and galaxy evolution in regions of high and low density is investigated. The module includes a look at modern instrumentation used in extragalactic astrophysics. Specialist lecturers from within the galaxy evolution research group will provide a direct link between material learnt in lectures and research currently being undertaken at the University of St Andrews.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures occasionally replaced by tutorials			
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Dr V Wild			
Lecturer(s)/Tutor(s):	Dr V Wild, Dr A M Weijmans (TBC)			

AS4011 The Physics of Nebulae and Stars 1

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	10.00 am Mon, Tue, Thu (TBC)			
This module introduces the physics of astrophysical plasmas, as found in stars and interstellar space, where interactions between matter and radiation play a dominant role. A variety of absorption, emission, and scattering processes are introduced to describe exchanges of energy and momentum, which link up in various contexts to control the state and motion of the matter, to regulate the flow of light through the matter, and to impress fingerprints on the emergent spectrum. The theory is developed in sufficient detail to illustrate how astronomers interpret observed spectra to infer physical properties of astrophysical plasmas. Applications are considered to photo-ionise nebulae, interstellar shocks, nova and supernova shells, accretion discs, quasar-absorption-line clouds, radio synchrotron jets, radio pulsars, and x-ray plasmas. Monte-Carlo computational techniques are introduced to model radiative transfer.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures occasionally replaced by whole-group tutorials.			
Assessment pattern:	2-hour Written Examination = 75%, Coursework = 25%			
Module Co-ordinator:	Dr K Wood			
Lecturer(s)/Tutor(s):	Dr K Wood (TBC)			

AS4012 The Physics of Nebulae and Stars 2

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	11.00 am odd Mon, Wed, Fri, 3.00 pm even Tue (TBC)			

This module develops the physics of stellar interiors and atmospheres from the basic equations of stellar structure introduced in AS2001/AS2101 using the radiative transfer concepts developed in Nebulae and Stars I. Topics include: the equation of state that provides pressure support at the high temperatures and densities found in normal and white-dwarf stars; the interaction of radiation with matter, both in terms of radiation-pressure support in super-massive stars and in terms of the role of opacity in controlling the flow of energy from the stellar interior to the surface; the equation of radiative transfer and the effects of local temperatures, pressures and velocity fields on the continuum and line absorption profiles in the emergent spectrum. Computer-aided tutorial exercises illustrate the computational schemes that represent one of the triumphs of late twentieth-century physics, in their ability to predict the observable properties of a star from its radius and luminosity, which in turn are determined by its mass, age and chemical composition.

Programme module type:	Optional for MSc in Physics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures occasionally replaced by whole-group tutorials.
Assessment pattern:	2-hour Written Examination = 75%, Coursework = 25%
Module Co-ordinator:	Prof A C Cameron
Lecturer(s)/Tutor(s):	Prof A C Cameron and Dr P Woitke (TBC)

AS4015 Gravitational and Accretion Physics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	12.00 noon odd Mon, Wed, Fri, 3.00 pm even Mon (TBC)			

This theoretical module is open to both physics and astrophysics students. It aims to explore the basics of gravitational dynamics and its application to systems ranging from planetary and stellar systems to clusters of galaxies. The dynamics responsible for the growth of super-massive black holes in galaxies and the accretion discs in stellar systems are also covered. Starting from two-body motion and orbits under a central-force law, the module describes the calculation of extended potentials and their associated orbits. The use of the virial theorem and the statistical treatment of large numbers of selfgravitating bodies is then developed with application to stellar systems. Applications of these methods are made to several different astrophysical objects ranging from collisions in globular clusters to the presence of dark matter in the universe.

Programme module type:	Optional for MSc in Physics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures occasionally replaced by whole-group tutorials.
Assessment pattern:	**As used by St Andrews:** 2-hour Written Examination = 100%
Module Co-ordinator:	Prof I Bonnell
Lecturer(s)/Tutor(s):	Prof I Bonnell (TBC)

AS4025 Observational Astrophysics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	2.00 pm - 5.30 pm Mon and Thu, plus some nights. (TBC)			
This is an observational and laboratory-based module that introduces students to the hands-on practical aspects of planning observing programmes, conducting the observations and reducing and analysing the data. Students use the James Gregory Telescope for CCD imaging and structural analysis of galaxies, and for CCD photometry of transiting exoplanet candidates. Further sources of data may be made available from international observatories. Observations are also secured at the University Observatory using a student-built radio telescope to observe low-frequency radio emission from the Galactic plane. Students gain experience in observation, data analysis, the UNIX operating system, standard astronomical software packages and modelling, and report writing.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 x 3.5-hour laboratories plus supervised work in the observatory.			
Assessment pattern:	Coursework = 100%			
Module Co-ordinator:	Dr C Cyganowski			
Lecturer(s)/Tutor(s):	Dr A Scholz, Dr J Greaves, Dr P A S Cruickshank, Dr C Cyganowski (TBC)			

AS5002 Magnetofluids and Space Plasmas

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	This module is intended for students in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	11.00 am Mon, Tue, Thu (TBC)			
This module is aimed at both physics and astrophysics students with interests in the physics of plasmas. The interaction of a magnetic field with an ionized gas (or plasma) is fundamental to many problems in astrophysics, solar- terrestrial physics and efforts to harness fusion power using tokamaks. The syllabus comprises: Solar-like magnetic activity on other stars. The basic equations of magneto-hydrodynamics. Stellar coronae: X-ray properties and energetics of coronal loops. Energetics of magnetic field configurations. MHD waves and propagation of information. Solar and stellar dynamos: mean field models. Star formation: properties of magnetic cloud cores, magnetic support. Physics of accretion discs: transport of mass and angular momentum. Accretion on to compact objects and protostars. Rotation and magnetic fields in protostellar discs. Rotation distributions of young solar-type stars. Magnetic braking via a hot, magnetically channelled stellar wind.				
Programme module type:	Optional for Postgraduate programmes within the School.			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Prof M M Jardine			
Lecturer(s)/Tutor(s):	Prof M M Jardine (TBC)			

AS5003 Contemporary Astrophysics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	12.00 noon Wed, Fri and 3.00 pm Mon (TBC)			
This module will provide an annual survey of the latest, most interesting, developments in astronomy and astrophysics at the research level. Emphasis will be placed upon the application of knowledge and expertise gained by students in their other modules to these current research topics.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Substantial astronomy knowledge and skills.			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures and some tutorials			
Assessment pattern:	**As defined by QAA:** Written Examinations = 100%, Practical Examinations = 0%, Coursework = 0%			
	As used by St Andrews: 2-hour Written Examination = 100%			
Re-Assessment:	Oral Re-Assessment, capped at grade 7			
Module Co-ordinator:	Dr C Helling			
Lecturer(s)/Tutor(s):	Dr C Helling, Dr G Laibe, Dr C Villforth (TBC)			

PH4022 Nuclear and Particle Physics

SCOTCAT Credits:	10	SCQF Level 10	**Semester:**	1
Planned timetable:	9.00 am Wed and Fri (TBC)			
The aim of this module is to describe in terms of appropriate models, the structure and properties of the atomic nucleus, the classification of fundamental particles and the means by which they interact. The syllabus includes: nuclear sizes, binding energy, spin dependence of the strong nuclear force; radioactivity, the semi-empirical mass formula; nuclear stability, the shell model, magic numbers; spin-orbit coupling; energetics of beta-decay, alpha-decay and spontaneous fission; nuclear reactions, resonances; fission; electroweak and colour interactions, classification of particles as intermediate bosons, leptons or hadrons. Standard model of leptons and quarks, and ideas that go beyond the standard model.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 90%, Coursework = 10%			
Module Co-ordinator:	Dr A Kohnle			
Lecturer(s)/Tutor(s):	Dr A Kohnle			

PH4025 Physics of Electronic Devices

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	9.00 am even Mon, Tue, Thu, 3.00 pm odd Mon (TBC)			
The module describes the physical phenomena involved in the operation of semiconductor devices, and then shows how the phenomena determine the properties of specific devices such as the transistor. Although only a few devices are described, the student taking the module should acquire a sufficient background to understand a wide variety of modern semiconductor devices. The module covers: semiconductor properties: band gaps, optical and electrical properties; conduction in an electric field and by diffusion; factors determining the concentrations of electrons and holes; the continuity equation; properties of pn junctions and Schottky diodes; typical devices: bipolar transistor, field-effect transistor, MOSFET, light emitting diodes, semiconductor lasers.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr G Turnbull			
Lecturer(s)/Tutor(s):	Dr G Turnbull, Dr L O'Faolain			

PH4026 Signals and Information

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	11.00 am odd Mon, Wed, Fri, 2.00 pm even Mon (TBC)			
This module gives an introduction to what are signals and information, and how they are measured and processed. It also covers the importance of coherent techniques such as frequency modulation and demodulation and phase sensitive detection. The first part of the module concentrates on information theory and the basics of measurement, with examples. Coherent signal processing is then discussed, including modulation/demodulation, frequency mixing and digital modulation. Data compression and reduction ideas are illustrated with real examples and multiplexing techniques are introduced. The module concludes with a discussion of basic antenna principles, link gain, and applications to radar.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr P Cruickshank			
Lecturer(s)/Tutor(s):	Dr P Cruickshank			

PH4027 Optoelectronics and Nonlinear Optics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	9.00 am Tue, Thu, 3.00 pm Fri (TBC)			
The module provides an introduction to the basic physics underpinning optoelectronics and nonlinear optics, and a perspective on contemporary developments in the two fields. The syllabus includes: an overview of optoelectronic devices and systems; optical modulators; acousto-optics; Bragg and Raman-Nath; propagation of light in anisotropic media; electro-optics; waveguide and fibre optics; modes of planar guides; nonlinear optics; active and passive processes in second and third order; second harmonic generation; phase matching; coupled wave equations; parametric oscillators; self-focusing and self-phase-modulation; optical bistability; phase conjugation; solitons; Rayleigh; Raman and Brillouin scattering.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Prof I D W Samuel			
Lecturer(s)/Tutor(s):	Prof I D W Samuel, Dr M Mazilu			

PH4028 Advanced Quantum Mechanics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	12.00 noon Tue and Thu (TBC)			
This module builds on the material of PH3061 and PH3062 Quantum Mechanics 1 and 2 to present some of the important current and advanced topics in quantum mechanics. The mathematics of complex analysis is introduced to allow this to be used for relevant quantum mechanics problems. Scattering theory is developed using partial waves and Green's functions, leading to a discussion of quantum degenerate gases. Advanced topics in perturbation theory including WKB approximation for exploring differential equations. The density matrix formalism as the general state description in open quantum systems is presented; open system dynamics are described within the formalism of the density matrix master equation. Quantum information processing is covered, including concepts such as qubits, quantum entanglement, quantum teleportation, and measurement based quantum computing.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and some tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr B Lovett			
Lecturer(s)/Tutor(s):	Dr B Lovett			

PH4031 Fluids

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	11.00 am even Mon, Tue, Thu, 2.00 pm odd Mon (TBC)			
This module provides an introduction to fluid dynamics, and addresses the underlying physics behind many everyday flows that we see around us. It starts from a derivation of the equations of hydrodynamics and introduces the concept of vorticity and the essentials of vorticity dynamics. The influence of viscosity and the formation of boundary layers is described with some straightforward examples. The effect of the compressibility of a fluid is introduced and applied to shock formation and to the conservation relations that describe flows through shocks. A simple treatment of waves and instabilities then allows a comparison between theory and readily-observed structures in clouds, rivers and shorelines.				
Programme module type:	Optional for MSc in Physics			
Required for:	AS5002 (strongly recommended, though not required)			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures and some tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Prof M Jardine			
Lecturer(s)/Tutor(s):	Prof M Jardine			

PH4032 Special Relativity and Fields

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	3.00 pm Tue, 4.00 pm Tue, Fri (TBC)			
The module analyses classical fields in physics such as the electromagnetic field. Fields are natural ingredients of relativity, because they serve to communicate forces with a finite velocity (the speed of light). The module covers the tensor formalism of special relativity, relativistic dynamics, the Lorentz force, Maxwell's equations, retarded potentials, symmetries and conservation laws, and concludes with an outlook to general relativity.				
Programme module type:	Optional for MSc in Physics			
Required for:	PH5011 (recommended, though not required)			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 75%, Coursework (assessed tutorial questions) = 25%			
Module Co-ordinator:	Dr N Korolkova			
Lecturer(s)/Tutor(s):	Dr N Korolkova			

PH4034 Laser Physics 1

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	9.00 am Mon, 12.00 noon Wed, Fri (TBC)			
This module presents a basic description of the main physical concepts upon which an understanding of laser materials, operations and applications can be based. The syllabus includes: basic concepts of energy-level manifolds in gain media, particularly in respect of population inversion and saturation effects; conditions for oscillator stability in laser resonator configurations and transverse and longitudinal cavity mode descriptions; single longitudinal mode operation for spectral purity and phase locking of longitudinal modes for the generation of periodic sequences of intense ultrashort pulses (i.e. laser modelocking); illustrations of line-narrowed and modelocked lasers and the origin and exploitability of intensity-induced nonlinear optical effects.				
Programme module type:	Optional for MSc in Physics			
Required for:	PH5016 (unless PH4035 is taken), PH5018 - also recommended for PH5005			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 90%, Coursework = 10%			
Module Co-ordinator:	Dr F Koenig			
Lecturer(s)/Tutor(s):	Dr F Koenig			

PH4035 Principles of Optics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	12.00 noon Mon, Wed, Fri (TBC)			
This module formulates the main aspects of physics used in modern optics, lasers and optoelectronic systems. Topics covered include: polarised light and its manipulation, with descriptions in terms of Jones' vectors and matrices; Fresnel's equations for transmittance and reflectance at plane dielectric interfaces; reflection and transmission of multi-layer thin films plus their use in interference filters; interpretation of diffraction patterns in terms of Fourier theory; spatial filters; the theory and use of Fabry-Perot etalons; laser cavities and Gaussian beams.				
Programme module type:	Optional for MSc in Physics			
Required for:	PH5016 (unless PH4034 is taken)			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 75%, Coursework = 25%			
Module Co-ordinator:	Dr F Koenig			
Lecturer(s)/Tutor(s):	Dr F Koenig			

PH4036 Physics of Music

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	12.00 noon Mon, Tue, Thu (TBC)			
Musical instruments function according to the laws of physics contained in the wave equation. Wind instruments, the human voice and the acoustics of concert halls can be explained largely by considering waves in the air, but understanding drums, percussion, string instruments and even the ear itself involves studying the coupling of waves in various media. The concepts of pitch, loudness and tone are all readily explained in quantitative terms as are the techniques that musicians and instrument makers use to control them. The analysis of musical instruments naturally culminates in a look at how musical sound may be synthesised.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr J Kemp			
Lecturer(s)/Tutor(s):	Dr J Kemp			

PH4037 Physics of Atoms

SCOTCAT Credits:	10	SCQF Level 10	**Semester:**	1
Planned timetable:	11.00 am Tue, Thu (TBC)			
This module provides a rational basis to the identification of atomic energy states and the various interactions of electrons within atoms. The syllabus includes: electron cloud model of an atom; electron spin and magnetic moment; spin-orbit interactions; one, two and many-electron systems; selection rules and line intensities for electric-dipole transitions; Lande g-factors; weak Zeeman and strong Paschen-Back magnetic field effects; hyperfine structure and Lamb shifts.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr N Korolkova			
Lecturer(s)/Tutor(s):	Dr N Korolkova, Prof P Wahl, Dr G Bruce			

PH4038 Lagrangian and Hamiltonian Dynamics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	2
Planned timetable:	10.00 am odd Mon, Tue, Thu, 2.00 pm even Fri (TBC)			
The module covers the foundations of classical mechanics as well as a number of applications in various areas. Starting from the principle of least action, the Lagrangian and Hamiltonian formulations of mechanics are introduced. The module explains the connection between symmetries and conservation laws and shows bridges between classical and quantum mechanics. Applications include the central force problem (orbits and scattering) and coupled oscillators.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 or 3 lectures and some tutorials			
Assessment pattern:	2-hour Written Examination = 75%, Coursework = 25%			
Module Co-ordinator:	Dr B Braunecker			
Lecturer(s)/Tutor(s):	Dr B Braunecker			

PH4039 Solid State Physics

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	11.00 am Wed, Fri, 2.00 pm Fri (TBC)			
This module is intended to show how the various thermal and electrical properties of solids are related to the nature and arrangement of the constituent atoms in a solid. For simplicity, emphasis is given to crystalline solids. The module examines: symmetry properties of crystals; common crystalline structures; the behaviour of waves in crystals; waves of atomic motion, leading to thermal properties; electronic energy states: conductors, insulators, semiconductors; electrical properties arising from the wave nature of electrons; examples of the fundamental theory applied to typical solids such as simple metals, silicon and other semiconductors, and magnetic materials.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials			
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Prof S Lee			
Lecturer(s)/Tutor(s):	Prof S Lee			

PH4105 Physics Laboratory 2

SCOTCAT Credits:	15	SCQF Level 10	**Semester:**	1
Planned timetable:	2.00 pm - 5.30 pm Mon and 2.00 pm - 5.30 pm Thu (TBC)			
The aims of the module are (i) to familiarise students with a wide variety of experimental techniques and equipment, and (ii) to instil an appreciation of the significance of experiments and their results. The module consists of sub-modules on topics such as solid state physics, optics, interfacing, and signal processing.				
Programme module type:	Optional for MSc in Physics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 x 3.5-hour laboratories.			
Assessment pattern:	Coursework = 100%			
Module Co-ordinator:	Dr C Rae			
Lecturer(s)/Tutor(s):	Dr C Rae and others			

PH5002 Foundations of Quantum Mechanics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Mon, Tue, Fri (TBC)			
This module consists of seven parts: (i) classical and quantum systems; (ii) vector spaces, Hilbert spaces, operators and probability; (iii) basic postulates of quantum mechanics for observables with discrete spectra; (iv) illustrative examples; (v) treatment of continuous observables in terms of probability distribution functions and the spectral functions; (vi) quantum theory of orbital and spin angular momenta, Pauli-Schrodinger equation and its applications; (vii) introduction to relativistic quantum mechanics.				
Programme module type:	Optional for some Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant Quantum Mechanics			
Required for:	Recommended, but not required, for PH5004			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Dr K Wan			
Lecturer(s)/Tutor(s):	Dr K Wan			

PH5003 Group Theory

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	12.00 noon Wed, Fri, 3.00 pm Mon (TBC)			
This module explores the concept of a group, including groups of coordinate transformations in three-dimensional Euclidean space; the invariance group of the Hamiltonian operator; the structure of groups: subgroups, classes, cosets, factor groups, isomorphisms and homorphisms, direct product groups; introduction to Lie groups, including notions of connectedness, compactness, and invariant integration; representation theory of groups, including similarity transformations, unitary representations, irreducible representations, characters, direct product representations, and the Wigner-Eckart theorem; applications to quantum mechanics, including calculation of energy eigenvalues and selection rules.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant undergraduate mathematics and physics.			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	2-hour Written Examination = 100%			
Module Co-ordinator:	Prof J Cornwell			
Lecturer(s)/Tutor(s):	Prof J Cornwell			

PH5004 Quantum Field Theory

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Thu, 3.00 pm Tue, Fri (TBC)			
This module presents an introductory account of the ideas of quantum field theory and of simple applications thereof, including quantization of classical field theories, second quantization of bosons and fermions, the failure of single particle interpretation of relativistic quantum mechanics, solving simple models using second quantization, Feynman's path integral approach to quantum mechanics and its relation to classical action principles, field integrals for bosons and fermions, the relationship between path integral methods and second quantization.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant undergraduate mathematics and physics		**Co-requisite(s):**	At least one of PH5002 and PH5012 is recommended but not compulsory.
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	Written Examinations = 90%, Practical Examinations = 0%, Coursework = 10% 2-hour Written Examination = 90%, Coursework = 10%			
Module Co-ordinator:	Dr J Keeling			
Lecturer(s)/Tutor(s):	Dr J Keeling			

PH5005 Laser Physics 2

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	10.00 am Mon, Tue, Wed, Thu (TBC)			
Quantitative treatment of laser physics embracing both classical and semiclassical approaches; transient/dynamic behaviour of laser oscillators including relaxation oscillations, amplitude and phase modulation, frequency switching, Q-switching, cavity dumping and mode locking; design analysis of optically-pumped solid state lasers; laser amplifiers including continuous-wave, pulsed and regenerative amplification; dispersion and gain in a laser oscillator - role of the macroscopic polarisation; unstable optical resonators, geometric and diffraction treatments; quantum mechanical description of the gain medium; coherent processes including Rabi oscillations; semiclassical treatment of the laser; tunable lasers.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant mathematics and physics			
Anti-requisite(s):	PH5018, PH5180			
Learning and teaching methods and delivery:	**Weekly contact**: 4 lectures or tutorials.			
Assessment pattern:	Written Examinations = 100%, Practical Examinations = 0%, Coursework = 0% 2.5-hour (open notes) Examination = 100%			
Module Co-ordinator:	Dr B Sinclair			
Lecturer(s)/Tutor(s):	Prof M Dunn, Dr L O'Faolain, Dr B Sinclair			

PH5011 General Relativity

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	9.00 am Wed, Fri, 3.00 pm Thu (TBC)			
This module covers: inertial frames, gravity, principle of equivalence, curvature of spacetime; basic techniques of tensor analysis; Riemannian spaces, metric tensor, raising and lowering of indices, Christoffel symbols, locally flat coordinates, covariant derivatives, geodesics, curvature tensor, Ricci tensor, Einstein tensor; fundamental postulates of general relativity: spacetime, geodesics, field equations, laws of physics in curved spacetime; distances, time intervals, speeds; reduction of equations of general relativity to Newtonian gravitational equations; Schwarzschild exterior solution, planetary motion, bending of light rays, time delays; observational tests of general relativity; Schwarzschild interior solution, gravitational collapse, black holes.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant mathematics and physics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	Written Examinations = 100%, Practical Examinations = 0%, Coursework = 0% 2-hour Written Examination = 100%			
Module Co-ordinator:	Dr H Zhao			
Lecturer(s)/Tutor(s):	Dr H Zhao			

PH5012 Quantum Optics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	11.00 am Mon, (9.00 am Tue, Thu - weeks 1 - 6, 11.00 am Tue, Thu - weeks 7 – 12) (TBC)			
Quantum optics is the theory of light that unifies wave and particle optics. Quantum optics describes modern high-precision experiments that often probe the very fundamentals of quantum mechanics. The module introduces the quantisation of light, the concept of single light modes, the various quantum states of light and their description in phase space. The module considers the quantum effects of simple optical instruments and analyses two important fundamental experiments: quantum-state tomography and simultaneous measurements of position and momentum.				
Programme module type:	Optional for a Postgraduate programme in the School.			
Pre-requisite(s):	Relevant quantum mechanics and mathematics			
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.			
Assessment pattern:	Written Examinations = 100%, Practical Examinations = 0%, Coursework = 0% 2-hour Written Examination = 100%			
Module Co-ordinator:	Dr F Koenig			
Lecturer(s)/Tutor(s):	Dr F Koenig, Dr N Korolkova			

PH5014 The Interacting Electron Problem in Solids

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	4.00 pm Mon, Tue, Thu (TBC)			
The aim of this module is to give an overview of developments in modern condensed matter physics. The difficulties of a full quantum mechanical treatment of electrons with strong interactions will be discussed. Common existing approaches such as the Hubbard and t-J models and Fermi liquid theory will be compared. It will be shown that, although microscopic models can explain aspects of magnetism, they have little chance of capturing many other features of the fascinating low-energy physics of these systems. Instead, we introduce the principle of emergence, and show how it suggests radically new approaches to the problem of complexity in condensed matter physics and beyond. In this module, formal lectures will be combined with reading assignments, and the assessment will be based on marked homework together with an oral presentation followed by questions.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant solid state physics, quantum mechanics and mathematics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and some tutorials.			
Assessment pattern:	Written Examinations = 0%, Practical Examinations = 50%, Coursework = 50% Coursework = 50%, Presentation plus Oral Examination = 50%			
Module Co-ordinator:	Dr C Hooley			
Lecturer(s)/Tutor(s):	Dr C Hooley			

PH5015 Applications of Quantum Physics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	12.00 noon Mon, Tue, Thu (TBC)			
Quantum physics is one of the most powerful theories in physics yet is at odds with our understanding of reality. In this module we show how laboratories around the world can prepare single atomic particles, ensembles of atoms, light and solid state systems in appropriate quantum states and observe their behaviour. The module includes studies of laser cooling, Bose-Einstein condensation, quantum dots and quantum computing. An emphasis throughout will be on how such quantum systems may actually turn into practical devices in the future. The module will include assessment based on tutorial work and a short presentation on a research topic.				
Programme module type:	Optional for Postgraduate programmes in the School.			
Pre-requisite(s):	Relevant physics and mathematics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures (x 11 weeks) and a further 2 x 1-hour tutorials, 1 x 3-hour research lab visit, 3 hours student presentations during the semester.			
Assessment pattern:	Written Examinations = 80%, Practical Examinations = 0%, Coursework = 20% 2-hour Written Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Prof K Dholakia			
Lecturer(s)/Tutor(s):	Prof K Dholakia, Dr M Mazilu			

PH5016 Biophotonics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Normally only taken in the final year of an MPhys or MSci programme involving the School			
Planned timetable:	9.00 am Mon, Wed, Fri (TBC)			
The module will expose students to the exciting opportunities offered by applying photonics methods and technology to biomedical sensing and detection. A rudimentary biological background will be provided where needed. Topics include fluorescence microscopy and assays including time-resolved applications, optical tweezers for cell sorting and DNA manipulation, photodynamic therapy, lab-on-a-chip concepts and bio-MEMS. Two thirds of the module will be taught as lectures, including guest lectures by specialists, with the remaining third consisting of problem-solving exercises, such as writing a specific news piece on a research paper, assessed tutorial sheets and a presentation. A visit to a biomedical research laboratory using various photonics methods will also be arranged.				
Programme module type:	Optional for Postgraduate programmes in the School Optional for EngD Photonics Programme			
Pre-requisite(s):	Relevant physics and mathematics			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and some tutorials.			
Assessment pattern:	Written Examinations = 80%, Practical Examinations = 0%, Coursework = 20% 2-hour Written Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Dr C T A Brown			
Lecturer(s)/Tutor(s):	Dr C T A Brown, Prof M C Gather, Dr C Penedo			

PH5023 Monte Carlo Radiation Transport Techniques

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Mon, Tue, Fri (TBC)			

This module introduces the theory and practice behind Monte Carlo radiation transport codes for use in physics, astrophysics, atmospheric physics, and medical physics. Included in the module: recap of basic radiation transfer; techniques for sampling from probability distribution functions; a simple isotropic scattering code; computing the radiation field, pressure, temperature, and ionisation structure; programming skills required to write Monte Carlo codes; code speed-up techniques and parallel computing; three-dimensional codes. The module assessment will be 100% continuous assessment comprising homework questions and small projects where students will write their own and modify existing Monte Carlo codes.

Programme module type:	Optional for Astronomy and Physics
Pre-requisite(s):	Relevant physics, mathematics and computing
Learning and teaching methods and delivery:	**Weekly contact**: 3 hours of lectures (x 5 weeks), 1-hour tutorials (x 5 weeks)
Assessment pattern:	Written Examinations = 0%, Practical Examinations = 0%, Coursework = 100% Coursework = 100%
Module Co-ordinator:	Dr K Wood
Lecturer(s)/Tutor(s):	Dr K Wood

PH5024 Surfaces, Symmetry, and Topology in Condensed Matter Physics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Available only to those in the final year of an MPhys programme			
Planned timetable:	10.00 am Tue, Wed, Thu (TBC)			

This module focuses on current topics in modern solid state physics, concentrating on the rich structural and electronic phases that can be stabilized at surfaces of materials. The first part will provide an overview of the distinct environment which surfaces provide, as well as detailing the experimental probes that can be used to investigate them. The second part of the module will introduce the concepts of topology in the context of electronic states in condensed matter systems. It will concentrate on topologically non-trivial states of matter, phases that are not characterised by spontaneous symmetry breaking but rather by a distinct topology of the underlying bulk electronic system, but with a particular focus on the implications for stabilizing exotic states at surfaces, and experimental probes of these. The module will employ continuous assessment for both formative and summative assessment, with an emphasis on developing skills in critical reading of scientific literature, presenting relevant works in class discussions and performing simple numerical calculations. Tutorial sessions will be used to provide constructive feedback on problem sheets throughout the course period. Full-class discussions in a “journal-club” style will aid in developing understanding of critical reading of research papers and complex topics, while written feedback on presentations will provide assessment of individual and group presentations delivered by students during the module.

Programme module type:	Optional for MPhys programmes
Pre-requisite(s):	PH3061, PH3062, (PH3081 or PH3082 or content from relevant mathematics modules), PH3080, PH4039, (PH4021 or PH4037)
Learning and teaching methods and delivery:	**Weekly contact**: 3 hours of lectures (x 7 weeks), 1-hour tutorials (x 4 weeks), 3-hour presentations (x 3 weeks)
Assessment pattern:	Written Examinations = 0%, Practical Examinations = 40%, Coursework = 60% Coursework = 100%
Module Co-ordinator:	Dr P Wahl
Lecturer(s)/Tutor(s):	Dr P Wahl, Dr P King

PH5177 Research Project (POED MSc)

SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	Summer
Availability restrictions:	This project module is organised and assessed with Heriot Watt as the lead institution in 2015/6 and alternate years thereafter, St Andrews in 2016/17 and alternate years after that. It is available only to those in the Photonics and Optoelectronic Devices MSc programme.			
Planned timetable:	Placement, full time.			
All POED MSc students carry out a ~3-month research project, in most cases carried out at a U.K. company. Part-time students who are industry employees may carry out the project at their own company. Students will have completed a literature survey prior to the project, and write a dissertation on the project which is assessed in September.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices MSc Programme.			
Pre-requisite(s):	Satisfactory completion of the taught element of Photonics and Optoelectronic Devices MSc programme .			
Learning and teaching methods and delivery:	**Weekly contact**: About 40 hours a week working on the project, with appropriate levels of supervision			
Assessment pattern:	Dissertation and Oral Examination = 100%			
Module Co-ordinator:	Dr B D Sinclair			
Lecturer(s)/Tutor(s):	Dr B D Sinclair			

PH5180 Laser Physics

SCOTCAT Credits:	20	SCQF Level 11	**Semester:**	1
Planned timetable:	10.00 am Mon, Tue, Wed, Thu (TBC)			
This module presents a description of the main physical concepts upon which an understanding of laser materials, operations, and applications can be based. These concepts include a treatment of light-matter interaction, gain, absorption and refractive index, rate-equation theory of lasers, gain and its saturation, frequency selection and tuning in lasers, transient phenomena, resonator and beam optics, and the principles and techniques of ultrashort pulse generation and measurement.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programmes. Optional for EngD Programme			
Pre-requisite(s):	Admission to a Taught Postgraduate programme within the School.			
Learning and teaching methods and delivery:	**Weekly contact**: 4 lectures/tutorials each week.			
Assessment pattern:	2.5-hour open-notes Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Dr B D Sinclair			
Lecturer(s)/Tutor(s):	Dr B D Sinclair, Dr C T A Brown, Prof M H Dunn, Dr L O'Faholain			

PH5181 Photonics Laboratory 1

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm - 5.30 pm Mon, Tue and Thu			
The photonics teaching laboratory gives training in the experimental photonics, and allows students the opportunity to explore photonics practically in a series of chosen open-ended investigations. Students use their knowledge and skills from the lecture modules, supplemented by additional reading, to investigate relevant photonic effects. Phase I involves work in small groups in introductory areas, then phase II allows primarily individual investigation of topics such as the second harmonic generation, optical parametric oscillation, erbium amplifiers, Nd lasers, optical tweezers, spectroscopy, remote sensing of speed, Brag reflectors, and holography. A formal lab report is included.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices MSc Programme and EngD Photonics Programme.			
Pre-requisite(s):	Admission to a Taught Postgraduate programme within the School.			
Learning and teaching methods and delivery:	**Weekly contact**: 3 x 2.5-hour practicals.			
Assessment pattern:	Coursework = 100%			
Module Co-ordinator:	Dr B D Sinclair			
Lecturer(s)/Tutor(s):	Dr B D Sinclair and others			

PH5182 Displays and Nonlinear Optics

SCOTCAT Credits:	10	SCQF Level 11	**Semester:**	1
Planned timetable:	To be arranged.			
The physics of polymers and liquid crystals is covered, showing the way to the use of semi-conducting polymers as light emitters, and the use of liquid crystals in displays and spatial light modulators. The nonlinear optics section of this module describes the physical ideas and application of second and third order nonlinear optics, including phenomena such as harmonic generation, parametric gain, saturated absorption, nonlinear refraction, Raman scattering, and optical solitons. The final section looks at second order nonlinear effects being exploited in optical parametric amplifiers and oscillators in the optical and THz regions.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices MSc Programme. Optional for EngD Photonics Programme			
Pre-requisite(s):	Admission to a Taught Postgraduate programme within the School.			
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and occasional tutorials.			
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%			
Module Co-ordinator:	Prof I D W Samuel			
Lecturer(s)/Tutor(s):	Prof I D W Samuel, Prof M H Dunn, Dr M Mazilu, Dr C F Rae			

PH5183 Photonics Applications

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	This module is intended for students in the final year of an MPhys or MSci programme involving the School, for those in the MSc in Photonics and Optoelectonic Devices, and for those on the EngD degree in Photonics.			
Planned timetable:	9.00 am Mon, Wed, Fri, 11.00 am Wed, Fri, 12.00 noon Mon, Tue, Thu Depending on options taken (TBC)			

Students on this module choose to do two of the following three sections:

Microphotonics and Plasmonics:This covers the Bragg effect, multilayer mirrors, defects causing confined cavity states, periodicity leading to bandstructure, scaling of bandstructure in reduced frequency, Bloch modes and photonic bandgap. It then considers photonic crystal waveguides, photonic crystal fibres, and supercontinuum generation in photonic crystal fibres. Plasmonics is based on oscillations of the free electronics in a metallic material. Resonances of Plasmons are the basis for a new class of materials called 'Metamaterials'. These are compared with photonic crystals. Applications include super-resolution imaging, optical cloaking, sensing, and surface enhanced Raman scattering.

Biophotonics:This will introduce students to the exciting opportunities offered by applying photonics methods and technology to biomedical sensing and detection. A rudimentary biological background will be provided where needed. Topics include fluorescence microscopy and assays including time-resolved applications, optical tweezers for cell sorting and DNA manipulation, photodynamic therapy, lab-on-a-chip concepts and bio-MEMS.

Optical Trapping and Atom Optics:Quantum physics is one of the most powerful theories in physics yet is at odds with our understanding of reality. In this course we show how laboratories around the world can prepare single atomic particles, ensembles of atoms, light and solid state systems in appropriate quantum states and observe their behaviour. The material includes optical cooling and trapping of atoms and ions, Fermi gases, studies of Bose-Einstein condensation, and matter-wave interferometry.

Students must not cover Biophotonics in both this module and PH5016/PH5264, and must not cover Optical Trapping and Atom Optics in both this module and PH5015/PH5267.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices MSc Programme. Optional for EngD Photonics Programme
Pre-requisite(s):	PG - Relevant physics and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: ~3 lectures and occasional tutorials.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Dr A Di Falco
Lecturer(s)/Tutor(s):	Dr C T A Brown, Dr D Cassettari, Dr M Mazilu, Dr A Di Falco, Dr L O'Faolain, Dr C Penedo

PH5301 Dissertation for MSc Programme

SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	2
Academic year:	2015/6			
Availability restrictions:	Only available tos tudents on the Physics MSc Programme			
Planned timetable:	To be arranged.			
This dissertation will be supervised by a member of the academic staff who will advise on the choice of subject and provide guidance during the work. The completed dissertation of not more than 15,000 words must be submitted by the stated date in August.				
Programme module type:	Compulsory for MSc Physics Postgraduate Programme.			
Pre-requisite(s):	Successful completion of the first two semesters of the Physics MSc programme in the School.			
Learning and teaching methods and delivery:	**Weekly contact**: Weekly meetings with supervisor			
Assessment pattern:	Written Examinations = %, Practical Examinations = %, Coursework = % Dissertation and Oral Examination = 100%			
Module Co-ordinator:	TBC			
Lecturer(s)/Tutor(s):	TBC			