List of Courses

Ross Knapman

Academic Year 2018-2019

PHYS 4151 Advanced Condensed Matter Physics

Raw Mark 82%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2018/phys4151/`

Soft Matter and Biological Physics Advanced material building on concepts from soft matter and biological physics covering phase transitions, membranes and liquid crystals in a biological context where appropriate. The course will focus on: the kinetics of phase transitions including the mechanisms of liquid-liquid demixing phase separation; self-assembly of micelles and membranes; liquid crystals; and soft and biological systems out of equilibrium.

Low Dimensional Solids Definition of low dimensional solids, relevant length and energy scales for manifestation of quantum confinement. Physical realisation of low dimensional structures: brief overview of the production of quantum dots, wires, nanotubes, graphene and semiconductor heterostructures. Zero dimensional solids: density of states in zero dimensions; optical properties of metallic and semiconducting quantum dots; electronic transport in zero dimensions: Coulomb blockade, Kondo effect, superconducting dots; applications of zero dimensional solids (emphasis on electronic/optical properties, e.g. single electron transistor, semiconductor nanocrystals as biological labels). One dimensional solids: density of states in one dimension: subbands and van Hove singularities, periodic boundary conditions in nanotubes; the special case of the 1D Fermi surface: Coulomb interaction and lattice coupling in 1D metals (breakdown of Fermi liquid behaviour, Peierls distortion); transport in one dimension: transport regimes, phase coherence, Landauer formula, resonant tunnelling, universal conductance fluctuations, localisation; quantised vibrations, heat capacity and thermal transport in one dimension; applications of one dimensional solids. Two dimensional solids: density of states and the Fermi surface in two dimensions; confinement in two dimensions: graphene and real (finite-depth) potential wells in semiconductor heterostructures; transport in two dimensional solids: conductivity of a two dimensional electron gas, subband filling; magneto-transport in two dimensions: resistivity and conductivity tensors, Büttiker-Landauer formalism, integer quantum Hall effect; applications of two-dimensional solids.

Optical Devices Review of the general theories of light/matter interaction: classical and quantum. Correspondence of the quantised nature of confined light-wave modes with one-dimensional matter wave solutions to the Schrödinger equation. Optical properties of materials, particularly doped semiconductors. Semiconductor (p-n) junctions. Optoelectronic devices using the semiconductor p-n junction: Photovoltaic/photoconductive detectors; Solar cell; Light emitting diode, (Franz Keldysh effect) Electro-absorption modulator. Optical waveguide devices: Passive devices (power splitters/combiners); Active devices (electro-optic/thermo-optic modulators, attenuators).

PHYS 4121 Atoms, Lasers and Qubits

Raw Mark 82%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2018/phys4121/`

Laser Physics Definition of a laser. Atom-light interactions. Absorption, spontaneous and stimulated emission. Line broadening mechanisms and emission linewidth. Population inversion and gain. Laser oscillator: cavity basics and threshold; gain saturation and output power. Population inversion in 3 and 4-level systems. Laser pumping with case studies of specific laser systems. Cavity modes and cavity stability. Gaussian beams. Cavity effects: single frequency operation. Cavity effects: Q switching and mode locking. Laser spectroscopy and optical frequency combs. Second harmonic generation and sum frequency generation. Case studies of laser applications.

Quantum Information and Computing Manipulation of qubits: Limits of classical computing. Feynman's insight. Quantum mechanics revision. Projection operators. Pauli matrices. Single-qubit operations: Resonant field, the Rabi solution. The Bloch sphere. The Ramsey technique. Two-qubit states. Tensor products. Correlations. Entanglement. Bell states. Two-qubit gates. The CNOT gate. Physical Realizations: The DiVincenzo criteria. Controlling the centre-of mass motion of atoms – laser cooling. Controlling the internal states of atoms. Trapping and manipulating single atoms. Rydberg states. Decoherence. Case studies of contemporary Quantum Information Processing.

PHYS 4141 Advanced Theoretical Physics

Raw Mark 75%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2018/phys4141/`

Quantum Theory in Condensed Matter Review of Bose-Einstein condensation in the ideal gas and in dilute atomic gases. Superfluidity, interactions, and excitations (phonons, rotons) in Helium II. Phenomenology of superconductivity. Ginzburg-Landau theory. Introduction to many-body quantum field theory in bosonic and fermionic systems. Phonons and Cooper pairs, BCS theory and quasiparticles. These will be developed in a rigerous and mathematical fashion.

Quantum Optics Quantization of light, creation and annihilation operators, Hamiltonian of the field, number states, coherent states, squeezed states, photon bunching and anti-bunching, density operator, pure states, mixed states, entangled states, decoherence, atom-light interactions, applications.

PHYS 4213 Project

Raw Mark 82%
60 University Credits
`https://www.dur.ac.uk/physics/modules/2018/phys4213/`

The project involves the equivalent of four half-days per week of study and research in the Michaelmas and Epiphany Terms, with a seminar presentation in the Epiphany Term and an oral examination of a report in the Easter Term. Normally, students are expected to carry out a research-based project as an appropriate training for a professional physicist. The project will be carried out with a research group in the Department. The list of projects available is published separately. Students should select five choices from this list and complete the web-based form as directed. In choosing project topics students should be aware of any special skills required.

The projects are designed to allow students to show their ability to carry out individual scientific investigation. They will also be able to demonstrate their ability to communicate their findings, verbally in the project seminar and in writing in the final report. Guidelines for the final report are provided to students at the outset of their projects at the beginning of the academic year.

Supervisors monitor progress and provide guidance on the development of the project during weekly meetings. Students will be able to obtain further help in their project by approaching their supervisors or other members of the appropriate research group.

Students will complete a preliminary report for supervisors for the beginning of the Epiphany Term. The preliminary report will not be formally assessed, but it is envisaged that, with little alteration, much of the content can be used in the final report. The last week of the Michaelmas Term is free of lectures and offers students an opportunity to work without interruption on their projects.

Students will present a seminar on the topic and progress of their project towards the end of the Epiphany Term. These presentations will be before an audience of staff and students, should last for 20 minutes and will form part of the summative assessment. Mr A.M. Skelton manages the arrangement of project seminars.

The deadline for the final report is advertised from the start of the academic year and falls near the start of the Easter Term, with the oral examinations normally taking place in the following week. A timetable for these will be posted by the end of the Epiphany Term. The examination will be conducted by the supervisor and an examiner. The examiner will normally be a member of the Department, but may be from outside the Department if that is more appropriate for the project concerned. A moderator will chair all examinations and will be responsible for ensuring a uniformity of procedure and assessment between different projects.

Important factors will be the planning and execution of the project and the interpretation and discussion of the results obtained in the context of prior and other parallel work in the area.

Academic Year 2017-2018

PHYS 3621 Foundations of Physics 3A

Raw Mark 74%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3621/`

Quantum Mechanics 3 Introduction to many-particle systems (wave function for systems of several particles, identical particles, bosons and fermions, Slater determinant) [10.1,10.2] The variational method (ground state, excited states, trial functions with linear variational parameters) [8.3] The ground state of two-electron atoms [10.4] The excited states of two-electron atoms (singlet and triplet states, exchange splitting, exchange interaction written in terms of spin operators) ["Atoms and Molecules", Ch. 7] Complex atoms (electronic shells, the central-field approximation) [10.5] The Born-Oppenheimer approximation and the structure of the hydrogen molecular ion; vibrational motion [10.6] The rigid rotator and rotational energy levels of molecules [6.4, 10.6] Time-dependent perturbation theory [9.1] Fermi's Golden Rule [9.2] Periodic perturbations [9.3] Two-level systems with harmonic perturbation, Rabi flopping [9.3] The Schrödinger equation for a charged particle in an EM field [11.1] The dipole approximation [11.1] Transition rates for harmonic perturbations [11.2] Absorption and stimulated emission [11.2] Einstein coefficients and spontaneous emission [11.3] Quantum jumps [17.5] Selection rules for electric dipole transitions [11.4] Lifetimes, line intensities, widths and shapes [11.5] The interaction of particles with a static magnetic field (spin and magnetic moment, particle of spin one-half in a uniform magnetic field, charged particles with uniform magnetic fields; Larmor frequency; Landau levels) [12.2] One-electron atoms in magnetic fields [12.3, Griffiths 6.4] Optional topics from the following list:

the sudden approximation, photoionization, calculation of the Landé g-factor, magnetic resonance, the van der Waals interaction, the ammonia maser and lasers.

Nuclear and Particle Physics Fundamental Interactions, symmetries and conservation Laws, global properties of nuclei (nuclides, binding energies, semi-empirical mass formula, the liquid drop model, charge independence and isospin), nuclear stability and decay (beta-decay, alpha-decay, nuclear fission, decay of excited states), scattering (elastic and inelastic relativistic kinematics scattering, cross sections, Fermi's golden rule, Feynman diagrams), geometric shapes of nuclei (kinematics, Rutherford cross section, Mott cross section, nuclear form factors), elastic scattering off nucleons (nucleon form factors), deep inelastic scattering (nucleon excited states, structure functions, the parton model), quarks, gluons, and the strong interaction (quark structure of nucleons, quarks in hadrons), particle production in electron-positron collisions (lepton pair production, resonances), phenomenology of the weak interaction (weak interactions, families of quarks and leptons, parity violation), exchange bosons of the weak interaction (real W and Z bosons), the Standard Model, quarkonia (analogy with Hydrogen atom and positronium, Charmonium, quark-antiquark potential), hadrons made from light quarks (mesonic multiplets, baryonic multiplets, masses and decays), the nuclear force (nucleon-nucleon scattering, the deuteron, the nuclear force), the structure of nuclei (Fermi gas model, shell Model, predictions of the shell model).

PHYS 3631 Foundations of Physics 3B

Raw Mark 80%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3631/`

Statistical Physics Introduction and basic ideas:- macro and microstates, distributions; distinguishable particles, thermal equilibrium, temperature, the Boltzmann distribution, partition functions, examples of Boltzmann statistics: spin-1/2 solid and localized harmonic oscillators; Gases: the density of states: fitting waves into boxes, the distributions, fermions and bosons, counting particles, microstates and statistical weights; Maxwell-Boltzmann gases: distribution of speeds, connection to classical thermodynamics; diatomic gases: Energy contributions, heat capacity of a diatomic gas, hydrogen; Fermi-Dirac gases: properties, application to metals and helium-3; Bose-Einstein gases: properties, application to helium-4, phoney bosons; entropy and disorder, vacancies in solids; phase transitions: types, ferromagnetism of a spin-1/2 solid, real ferromagnetic materials, order-disorder transformations in alloys; statics or dynamics? ensembles, chemical thermodynamics: revisiting chemical potential, the grand canonical ensemble, ideal and mixed gases; dealing with interactions: electrons in metals, liquid helium 3 and 4, real imperfect gases; statistics under extreme conditions: superfluid states in Fermi-Dirac systems, statics in astrophysical systems.

Condensed Matter Physics Part 1 Review of the effect of a periodic potential, energy gap. Fermi surfaces, reduced and extended zone schemes. Fermi surfaces and metals; electron and hole orbits, energy bands, De Haas–van Alphen effect. Diamagnetism and paramagnetism; Langevin equation; quantum theory of paramagnetism, Hund's rules, crystal field splitting, paramagnetism of conduction electrons, ferromagnetism and Antiferromagnetism; Curie point, exchange integral, magnons, Antiferromagnetism, magnetic susceptibility.

Condensed Matter Physics Part 2 Semiconductor crystals: crystal structures, band gaps, equations of motion, carrier concentrations of intrinsic and extrinsic semiconductors, law of mass action, transport properties, p-n junction. Superconductivity:Meissner effect, London equation, type I and type II superconductors, thermodynamics of superconductors, Landau-Ginzberg theory, Josephson junctions. Dielectrics and ferroelectrics: macroscopic and local electric fields, dielectric constant and polarizilbility, structural phase transitions.

PHYS 3641 Advanced Physics 3

Raw Mark 78%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3641/`

Soft Condensed Matter Physics An overview of soft matter and the length scales, time scales and forces that are relevant. Thermodynamics, phase transitions and equilibrium phase diagrams in soft condensed matter. Molecular and macroscopic descriptions of surfaces and interfaces. Particles diffusion and colloidal stability. Polymer structure, dynamics and elasticity. Polymer and block copolymer self-assembly.

Optical Properties of Solids Optical coefficients, complex refractive index, dielectric constant, classification of optical materials [Fox Chapter 1.1-1.4] Optics in the solid state: crystal symmetry, electronic bands, vibronic bands, density of states [Fox Chapter 1.5-1.6] Propagation of light in an optical medium: atomic, vibrational and free electron oscillators [Fox Chapter 2.1] The dipole oscillator model: Lorentz oscillator, Kramers-Kronig equations [Fox Chapter 2.2, Kittel Chapter 15] Dispersion, anisotropy, birefringence [Fox Chapter 2.3-2.4] Interband absorption: transition rates, joint density of states, indirect band absorption [Fox Chapter 3.1-3.3] Exciton states: binding energy, Frenkel excitons: alkali halides, organic molecules [Fox Chapter 4, Kittel Chapter15] Light emission in solids: interband luminescence emission, spontaneous emission rates, solid state optical devices (LEDs) [Fox Chapter 5.1-5.2, 5.4] Free electron effects in solids: plasma reflectivity, plasmons [Fox Chapter 7.1-7.3, 7.5, Kittel Chapter 14] Optical properties of molecules: electronic-vibrational coupling, configuration coordinate diagrams, Franck-Condon principle, Stokes shift [Fox Chapter 8.1-8.3, Kittel Chapter 15] Vibrational states: optically active phonons, polariton coupled optical-vibrational states, polarons, inelastic light scattering [Fox Chapter 10, Kittel Chapter 15] Nonlinear optics: nonlinear susceptibility, resonant non-linearities, frequency mixing [Fox Chapter 11.1-11.2]

Modern Atomic and Optical Physics Revision of fine structure; adding atomic angular momenta; term symbols; hyperfine structure; the F quantum number; atomic transitions and selection rules [Foot Chapter 2, Sections 4.5, and 4.6.] The hyperfine structure of hydrogen and alkali-metal atom ground states [Foot Sections 6.1.] Electric and magnetic dipole interactions. The electron distribution of a superposition of states. Spontaneous emission. The Einstein A coefficient [Foot Sections 1.7, 2.2.] Interaction of a 2-level atom with a resonant field. The Rabi solution. Stimulated emission [Foot Section 6.4.2, Chapter 7.] The Ramsey technique. Transit-time broadening [Foot Sections 7.4 and 8.2.] The Zeeman effect. The Breit-Rabi diagram for hydrogen and the alkali-metal atoms [Foot Section 6.3.] Light forces. Photon momentum. Laser cooling [Foot Chapter 9.] The atomic fountain clock [Foot Section 9.9] Frontiers of metrology.

PHYS 3561 Physics Problem Solving

Raw Mark 73%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3561/`

General Problems In each workshop students will attempt to solve problems which involve basic physical concepts. Advice and instruction will be provided by the members of staff supervising the class. They also provide opportunity for you to obtain further feedback on the self-assessed formative weekly problems. Each student will be allocated to attend one of the two groups, each of which will have a workshop fortnightly. To aid preparation for the May/June General Problems paper, there will be a ‘Collection’ examination near the end of the Michaelmas Term. The examinations will be open-book and will contain questions on topics that may not have been included in the classes. The workshops for this module are not compulsory.

Computing Project Employing their programming skills gained from the Level 2 module Laboratory

Skills and Practice, students will undertake a computational project in Physics selected from a wide range of problems reflecting the various research interests of the Department. Students will use the program they develop to produce a writen research report at the end of the course.

PHYS 3591 Mathematics Workshop

Raw Mark 75%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3591/`

Complex Analysis Analytic functions: functions of complex variable; functions differentiable in the complex sense; Cauchy-Riemann conditions; singularities; multiple-valued functions; complex integration and Cauchy's theorem; Taylor and Laurent series; poles and residues; residue theorem and definite integrals; residue theorem and series summation.

Infinite Dimensional Vector Spaces Vector Spaces and Hilbert spaces; Linear operators; Matrices; Eigenvalue Problems; Diagonalisation of Matrices; Co-ordinate Transformations; Tensor Calculus.

Calculus of Variations and Infinite Series Calculus of Variations: Euler-Lagrange equations; Classic variational problems: Brachystochrone; Lagrange Multipliers; Isoperimetric problem. Infinite Series: Convergence criteria; Familiar series; Transformation of series; Taylor series for analytic functions; Asymptotic series. Evaluation of Integrals: Change of variables, Gaussian and related integrals, Gamma Function, miscellaneous methods and tricks.

Integral Transforms Definition of an integral transform. Fourier transforms; derivation from Fourier series, basic properties and applications, including the convolution theorem, Parseval's relation, and the Wiener-Khinchin theorem. Discrete Fourier transform. Laplace transform; relation to Fourier transform, inverse transform and Bromwich integral, basic properties and applications.

PHYS 3661 Theoretical Physics 3

Raw Mark 80%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2017/phys3661/`

Relativistic Electrodynamics Einsteins postulates [12.1] The geometry of relativity [12.1] Lorentz transformations [12.1] Structure of space-time [12.1] Proper time and proper velocity [12.2] Relativistic energy and momentum [12.2] Relativistic Kinematics [12.2] Relativistic Dynamics [12.2] Magnetism as a relativistic phenomena [12.3] How the Fields transform [12.3] The Field Tensor [12.3] Electrodynamics in Tensor notation [12.3] Relativistic potentials [12.3] Scalar and Vector potentials [10.1] Gauge transformations [10.1] Coulomb gauge [10.1] Retarded potentials [10.2] Fields of a moving point charge [10.3] Dipole radiation [11.1] Radiation from point charges [11.2]

Quantum Theory 3 Scattering experiments and cross sections [13.1] Potential scattering (general features) [13.2] Spherical Bessel functions (application: the bound states of a spherical square well) [7.3 and 7.4] The method of partial waves (scattering phase shift, scattering length, resonances, applications) [13.3 and 13.4] The integral equation of potential scattering [13.5] The Born approximation [13.6] Collisions between identical particles [13.7] Introduction to multichannel scattering [13.8] The density matrix (ensemble averages, the density matrix for a spin-1/2 system and spin-polarization) [14.1, 14.2 and 14.3] Quantum mechanical ensembles and applications to single-particle systems [14.4 and 14.5] Systems of non-interacting particles (Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics, ideal Fermi-Dirac and Bose-Einstein gases) [14.6] The Klein-Gordon equation [15.1] The Dirac equation [15.2] Covariant formulation of Dirac theory [15.3] Plane wave solutions of the

Dirac equation [15.4] Solutions of the Dirac equation for a central potential [15.5] Negative energy states and hole theory [15.7] Non-relativistic limit of the Dirac equation [15.6] Measurements and interpretation (hidden variables, the EPR paradox, Bell's theorem, the problem of measurement) [17.1 to 17.4]

Academic Year 2016-2017

PHYS 2581 Foundations of Physics 2A

Raw Mark 76%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2581/`

Quantum Mechanics Summary of Level 1 Quantum Mechanics (the Schrödinger equation, the interpretation of the wave function, energy levels, plane waves) Wave packets and wave packet spreading [2.4] The momentum operator [2.3] Wave functions in momentum space; the delta function [2.4] The time-dependent Schrödinger equation [3.1] Conservation of probability [3.2] The Ehrenfest theorem [3.4] and the virial theorem [5.7] Stationary states [3.5] Example: the linear harmonic potential (energy levels and wave functions in terms of Hermite polynomials) [4.7] General solution of the time-dependent Schrödinger equation for a time-independent potential [3.8] Properties of the eigenfunctions of the Hamiltonian [3.7] Introduction to the formalism of quantum mechanics (quantum states, Dirac notation, dynamical variables and operators, eigenvalues and eigenvectors, expansion in eigenfunctions, expectation values) [3.3 and summary of Ch. 5] The Schrödinger equation in 3D Cartesian coordinates [7.1] The Schrödinger equation in spherical polar coordinates [7.2] Orbital angular momentum (differential operator) [6.1] Eigenfunctions and eigenvalues of L2 and Lz; spherical harmonics and their properties [6.3] The hydrogen atom (calculation of the energy levels and of the bound state wave functions, radial and angular distribution functions, reduced mass) [7.5] An introduction to spin, to 2-component spinors and to the addition of angular momenta [summary of 6.5, 6.8 and 6.10] The total angular momentum J and the eigenvalues of J2 and Jz [6.9] Time independent non-degenerate perturbation theory [8.1] Time independent degenerate perturbation theory [8.2 and Griffiths Ch. 6] Example: the Stark effect in the ground state and in the n = 2 states of atomic hydrogen [12.1] Quasi-degenerate states [8.2] Spin-orbit coupling and the fine structure of hydrogen [8.3 and Griffiths 6.3] Hyperfine splitting [Griffiths 6.5]

Electromagnetism Electrostatics: The Electrostatic Field, Divergence and Curl of Electrostatic Fields, Electric Potential, Work and Energy in Electrostatics, Conductors. Special Techniques: Laplace's Equation and Uniqueness Theorems, The Method of Images, Separation of Variables, Multipole Expansion. Electrostatic Fields in Matter: Polarization, The Field of a Polarized Object, The Electric Displacement, Linear Dielectrics. Magnetostatics: The Lorentz Force Law, The Biot-Savart Law, The Divergence and Curl of B, Magnetic Vector Potential. Magnetic Fields in Matter: Magnetization, The Field of a Magnetized Object, The Auxiliary Field H, Linear and Nonlinear Media. Electrodynamics: Electromotive Force, Electromagnetic Induction, Maxwell's Equations. Conservation Laws: Charge and Energy, Momentum. Electromagnetic Waves: Waves in One Dimension, Electromagnetic Waves in Vacuum, Electromagnetic Waves in Matter, Absorption and Dispersion, Guided Waves.

PHYS 2591 Foundations of Physics 2B

Raw Mark 83%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2591/`

Thermodynamics Revision of basic ideas, Heat, Zeroth law and temperature; Definition of state variables, forms of energy and chemical potential, the First Law; Heat engines and the Second law, Clausius inequality, Entropy and entropy change; Entropy change in reversible and non-reversible processes; Thermodynamic Potentials and Maxwell's Relations; Availability of Energy and applications of entropy; Heat and refrigeration cycles; Equilibrium and phase transitions, Clausius-Clapeyron equation; Third law of thermodynamics, obtaining low temperatures; Thermodynamics in action; Basic postulates of statistical mechanics, micro/mactostates, distinguishable and indistinguishable particles, Stirling's approximation, relationship to thermodynamics and entropy; Boltzmann distribution function; equipartition and the partition function; Bose-Einstein and Fermi-Dirac distribution functions, examples of 4He and electrons.

Condensed Matter Physics Review of crystal structures and their description: periodic arrays, lattices and bases, Miller indices. Wave Diffraction and the Reciprocal Lattice: Bragg's Law, scattered wave amplitude, Brillouin zones and structure factor. Crystal binding: Van der Waals solids, Ionic and covalent crystals, metals. Phonons I: Crystal vibrations: Vibrations of a linear chain with one and two atom bases, quantization and phonons. Phonons II: Thermal properties: Phonon heat capacity, Einstein and Debye models, anharmonicity and thermal conductivity. The classical Drude model of electrons: an attempt to explain electrons as classical particles. Free Electron Fermi Gas Model: Energy levels, the Fermi-Dirac distribution, heat capacity, electrical and thermal conductivity of metals, magnetic properties and the failure of the free electron model. Energy Bands: The nearly-free electron model, wave equation of an electron in a periodic potential, Bloch functions, Fermi surfaces, reduced and extended zone schemes. Bending of energy bands close to the Brillouin zone boundary: the effect of a periodic potential, effective masses, electrons and holes. Metals, Semimetals, Semiconductors and Insulators.

Modern Optics Review of EM [Hecht Section 2.8, 3.2 and Appendix 1] Plane waves and spherical waves [Hecht Section 2.7 and 2.9] Fourier transforms: Linearity, convolution, shifting, scaling [Hecht Chapter 11] Propagating the solution to the wave equation using the angular spectral method [Goodman Chapter 3] Gaussian beams [Hecht Section 13.1] Near-field (Fresnel) and far-field (Fraunhofer) diffraction [Hecht Section 10.1 and 10.3] Simple cases: single and double slits [Hecht Section 10.1 and 10.2] Simple cases: multiple slits [Hecht Section 10.1 and 10.2] Phasors [Hecht Section 4.5 and 4.11] 2D diffraction: letters, and circular apertures [Hecht Section 10.2.3 and 10.3] Diffraction limit: Rayleigh criterion, Heisenberg microscope [Hecht Section 10.2] Spatial filtering [Hecht Section 13.2] Babinet's Principle. Apodization [Hecht Section 10.3] Fabry Perot: Gaussian modes of a cavity [Hecht Section 9.6 and 13.1] Lasers and cavities [Hecht Section 13.1]

PHYS 2631 Theoretical Physics 2

Raw Mark 79%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2631/`

Classical Mechanics Lagrangian mechanics: d'Alembert's principle, constraints and degrees of freedom, generalized coordinates, velocities and forces, definition of Lagrangian and Hamiltonian, ignorable coordinates . Variational calculus and its application: Euler equation, Hamilton's principle, Lagrange multipliers and constraints. Linear oscillators: stable and unstable equilibrium, SHO and damped SHO, impulsive forces and Green's function, driven oscillators and resonance. One-dimensional systems and central forces: solution by quadrature, central force problem, gravitational attraction. Noether's theorem and Hamiltonian mechanics: angular momentum conservation, Noether's theorem, Hamilton's equations. Theoretical mechanics: canonical transformations, Poisson brackets. Rotating coordinate systems: angular velocity vector, finite and infinitesimal rotations in 3D, rotated and rotating reference frames, centrifugal, Coriolis and Euler forces, Foucault pendulum. Dynamics of rigid bodies: kinetic energy, moment of inertia tensor, angular momentum, Euler equations, Euler angles, motion of torque-free symmetric and asymmetric tops. Theory of small vibrations: two coupled pendulums, normal modes and normal coordinates.

Quantum Theory State of a system and Dirac notation [5.1] Linear operators, eigenvalues, etc, Hermitean operators [5.2] Expansion of eigenfunctions [5.3] Commutation relations, Heisenberg uncertainty [5.4] Unitary transforms [5.5] Matrix representations [5.6] SE and time evolution [5.7] Schrödinger, Heisenberg and Interaction pictures [5.8] Symmetry principles and conservation [5.10] Angular momentum (operator form) [6.1, 6.3] Orbital angular momentum (operator form) [6.2] examples: Particle on sphere/rigid rotator [6.4] General angular momentum (operator form) [6.5] Matrix representation of angular momentum operators [6.6] Spin angular momentum [6.7] Spin 1/2 [6.8] Pauli spin matrices [6.8] Total angular momentum [6.9] Addition of angular momentum [6.10]

PHYS 2641 Laboratory Skills and Electronics

Raw Mark 78%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2641/`

'Bridge' Project A team-based project providing a transition from Level 1 to Level 2 laboratory work. Students will work in teams on an extended project lasting one week, which will develop their problem-solving, teamwork and presentation skills. Each project will be in the form of a problem and the team will direct their research under the guidance of a member of staff. There is no "right way" to solve the problem and it is the team's responsibility to plan and carry out an approach in order to solve the problem. These projects will cover a wide range of physics problems, including astronomy and applications of physics, and you will be given the opportunity to select a project that interests you. Project titles and supervisors will be made available on DUO During Easter vacation and students will sign up for a project on a first come-first served basis early in Easter term.

Students will work in a team of typically 4 people to investigate a problem through research for 35 hours (1 week). The project will be directed by your team, with guidance from a staff member who will act as a supervisor and meet with the team for up to one hour per day. The team will have access to existing departmental teaching laboratory equipment and will be asked to create a webpage (wiki) about their investigation. Each member of the team will be expected to keep a good laboratory notebook with their results and experimental methods, and also to keep an online journal detailing their personal contribution to the project. The project will be assessed by an informal assessed discussion using the wiki, through the supervisor monitoring the progress and journal entries.

Computational Physics Functions, random numbers, intergration, linear algebra, ordinary differential equations.

Skills Labs An introduction to experimental physics at Level 2. This course has typically 30 minutes of instruction and two and a half hours of practical work per session. Students work in teams. The course emphasises the skills necessary for experimental physics. The main topics are experimental design, data/error analysis, cryogenics and an introduction to the Labview software used to control and log data from measurement devices. Recording and reporting results are also covered with training in the writing of both short and long reports and in oral presentations.

Careers Talks Invited speakers give presentations on employability and the applications of physics in enterprises.

Electronics Lectures Analog electronics. Components: introduction to circuit theory, networks and AC theory, passive filters. Systems: feedback and amplification, control circuits, oscillators, modulation and demodulation, noise, measurements and phase-sensitive detection.

Electronics Labs Four laboratory classes covering practical aspects relating to the lecture course content. Students then undertake an invigilated practical electronics assessment during one of the final two sessions in Epiphany term.

Critical Reading of Relevant Scientific Papers 1 three-hour session in Epiphany Term

Research-Led Investigation Long experiments in the physics laboratory, chosen from a list of titles. Students usually work in pairs but in some cases, individually.

PHYS 2611 Mathematical Methods in Physics

Raw Mark 78%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2611/`

Part I Vector algebra, Matrices and vector spaces, Vector calculus, Line and surface integrals, Fourier series, Fourier transforms, Laplace transforms.

Part II Higher order ODEs, Series solutions of ODEs, PDEs: general and particular solutions, PDEs: separation of variables, Special functions.

PHYS2621 Stars and Galaxies

Raw Mark 83%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2016/phys2621/`

Observational Techniques Telescopes.

Stars Binary stars and Stellar Parameters; The Classification of Stellar Spectra; Stellar Atmospheres; The Interior of Stars; The Sun; The Process of Star Formation; Post-Main-Sequence Stellar Evolution; Stellar Pulsation; The Degenerate Remnants of Stars; Black Holes; Close Binary Systems.

Galactic Astronomy The Milky Way Galaxy; The Nature of Galaxies; Galactic Evolution.

Academic Year 2015-2016

PHYS1122 Foundations of Physics 1

Raw Mark 69%
40 University Credits
`https://www.dur.ac.uk/physics/modules/2015/phys1122/`

Mechanics Motion along a straight line; motion in two or three dimensions; Newton's laws of motion; applying Newton's laws; work and kinetic energy; potential energy and energy conservation; momentum, impulse and collisions; rotation of rigid bodies; dynamics of rotational motion; equilibrium and elasticity; gravitation; periodic motion; fluid mechanics.

Thermodynamics Temperature and heat; thermal properties of matter; the first law of thermodynamics; the second law of thermodynamics.

Waves and Optics Mechanical waves; sound and hearing; the nature and propagation of light; geometric optics and optical instruments; interference; diffraction.

Electromagnetism Electric charge and electric field; Gauss's law; electric potential; capacitance and dielectrics; current, resistance and electromotive force; direct-current circuits; magnetic field and magnetic forces; sources of magnetic field; electromagnetic induction; inductance; electromagnetic waves.

Modern Physics Relativity; photons, electrons, atoms; the wave nature of particles; quantum mechanics; atomic structure; molecules and condensed matter; nuclear physics; particle physics and cosmology.

PHYS 1081 Introduction to Astronomy

Raw Mark 84%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2015/phys1081/`

A User's Guide to the Night Sky Introduction to the Night Sky, Naked Eye Astronomy, Motions in the Sky, the Celestial Sphere, Coordinate Systems, the Ecliptic, the Seasons, Solar and Sidereal Days, Precission of the Equinoxes, the Moon, Eclipses, the Planets, Sidereal and Synodic Periods, Apparent Motion of an Inferior Planet, Apparent Motion of a Superior Planet, Further Objects to observe with the Naked-Eye.

The Solar System Early Solar System models, Distances in the Solar System, Kepler's laws and Gravity, Terrestrial Planets, Gas Giants, Asteroids, Comets, Formation of the Solar System, Formation of the Earth-Moon system.

Sun, Stars and Stellar Evolution The Stars – measuring the stars, stellar classification, how the stars shine. The Sun as a star. Making sense of the 'zoo' – stellar evolution, star clusters and ages. Stellar deaths – supernovae, white dwarfs, neutron stars and black holes.

Astrobiology What is Astrobiology? The formation of our Solar System. Methods for the detection of extra-solar planets. Conditions for life: habitable zones. The prospects for finding extraterrestrial life.

Cosmic History The expanding Universe, the Big Bang, the cosmic microwave background radiation, dark matter.

The Milky Way and Beyond The Milky Way – the interstellar medium, mapping the Galaxy. The Milky Way's companions. Galaxies – the hubble sequence, spiral and elliptical galaxies, measuring distances. Clusters and Superclusters. Colliding galaxies. Active galaxies and quasars. Evidence for Dark Matter. The expansion of the Universe.

PHYS 1101 Discovery Skills in Physics

Raw Mark 78%
20 University Credits
`https://www.dur.ac.uk/physics/modules/2015/phys1101/`

Errors Lectures Errors in laboratory work: systematic and random errors, combination of errors, common sense in errors.
Introduction to Programming Computer programming and programming languages. Representations of numbers. Introduction to numerical computation. Programming in Python: variables, expressions, types, control flow, functions, arrays, input/output, objects and methods.
Skills Sessions Safety in the laboratory. Introduction to instrumentation: oscilloscopes, function generators, circuits. Verifying physical laws, measurement technique, statistics of measurement, dimensional analysis, graph plotting. Applications of material from the errors lectures. Electronic document preparation. Information literacy, including introduction to sources of reference material. The final skills session is devoted to a short one-on-one tutorial on laboratory report writing, based on a data analysis exercise, and practical tuition on the use of a spreadsheet application.

Discovery Experiments Introductory experiments in physics (one per week) using structured scripts, with students working in pairs. One of the sessions takes the form of an Enterprise Seminar. The results and observations made in the laboratory notebook during these sessions are formatively assessed.

Full Experiments Full experiments in physics including a mini extended-investigation (one lab session per week), with students working in pairs. Two experiments form the bases for a formatively and summatively-assessed extended written report respectively. One session is devoted to one-to-one oral feedback from the marker of the formatively-assessed report. One session is devoted to carrying out and recording the results of a simple scientific task, with the records kept being summatively assessed. One session is devoted to presenting the results from the mini extended-investigation.

MATH 1561 Single Mathematics A

Raw Mark 100%
20 University Credits
`https://www.dur.ac.uk/faculty.handbook/archive/module_description/?year=2015&module_code=MATH1561`

Basic functions and elementary calculus: including standard functions and their inverses, the Binomial Theorem, basic methods for differentiation and integration. Complex numbers: including addition, subtraction, multiplication, division, complex conjugate, modulus, argument, Argand diagram, de Moivre's theorem, circular and hyperbolic functions. Single variable calculus: including discussion of real numbers, rationals and irrationals, limits, continuity, differentiability, mean value theorem, L'Hopital's rule, summation of series, convergence, Taylor's theorem. Matrices and determinants: including determinants, rules for manipulation, transpose, adjoint and inverse matrices, Gaussian elimination, eigenvalues and eigenvectors, Groups, axioms, non-abelian groups

MATH 1571 Single Mathematics B

Raw Mark 92%
20 University Credits
`https://www.dur.ac.uk/faculty.handbook/archive/module_description/?year=2015&module_code=MATH1571`

Vectors: including scalar and vector products, derivatives with respect to scalars, two-dimensional polar coordinates. Ordinary differential equations: including first order, second order linear equations, complementary functions and particular integrals, simultaneous linear equations, applications. Fourier analysis: including periodic functions, odd and even functions, complex form. Functions of several variables: including elementary vector algebra (bases, components, scalar and vector products, lines and planes), partial differentiation, composite functions, change of variables, chain rule, Taylor expansions. Introductory complex analysis and vector calculus Multiple integration: including double and triple integrals. Introduction to probability: including sample space, events, conditional probability, Bayes' theorem, independent events, random variables, probability distributions, expectation and variance.

Some Notes

- The grading system in the UK is such that, in general, a lower raw mark indicates the same standard than in Germany. Specifically, the grading system is:
  - 70%+: First-Class Honours,

  - 60 - 69%: Second-Class Honours, Upper Division,
  - 50 - 59%: Second-Class Honours, Lower Division,
  - 40 - 49%: Third-Class Honours.

- When calculating the final grade, the second, third, and fourth years are weighted in the ratio 2:3:4 respectively (the first year's results don't contribute to the final degree classification). Within each year, modules are weighted by credits.