St Anne's College
University of Oxford

Studying Physics at Oxford

Physics is concerned with the study of the Universe from the smallest to the largest scale, why it is the way it is, and how it works. Physics principles underpin all of the other scientific disciplines, from chemistry through material science to biology. Oxford has one of the largest physics departments in the world and hosts an outstanding and broad teaching and research programme.

Studying Physics at St Anne's

At St. Anne's you will benefit from being taught by experts who are leaders in their respective fields. We have a vibrant and friendly student community who will welcome you into the fold. You will join with physics students at St. Anne's and also mix with the whole Oxford student physics cohort in lectures, classes and labs.

Study durations

You can apply to study physics as a single or joint subject.

	Ext AY	AY	Fall Term	Hilary and Trinity terms	Studied with other subjects
Physics	☑	☑	☑	☒	☑ Philosophy or Maths Please enquire about other subject possibilities. It is not possible to study physics with another science.

Courses

Visiting students would typically study the second or third year of the Oxford physics degree course, depending on the student's academic background and level, and join in lectures and tutorials with current St. Anne's undergraduates.

Second year Oxford physics courses are core classical physics topics: *mathematical physics, quantum mechanics, thermal physics, electromagnetism and optics*.

Third year courses are more cutting-edge topics: *subatomic physics, symmetries, special and general relativity, fluids, condensed matter and atomic physics* (all of which require a background in the second-year courses as a pre-requisite).

You can read more about these courses available in the pages below. Students are expected them to take all the courses offered in a given term to make up a reasonable course load. Visiting students cannot study any of the fourth year (MMathPhys or MPhys) courses. Oxford physics students sit exams in Trinity term and generally intensive revision tutorials are only available in that term. However, if availability exists, a mini-project may be possible as a substitution.

Pre-requisites

You will already be studying physics at your home institution. Ideally you will have completed courses equivalent to the first year of the Oxford degree course. If you wish to access third year Oxford courses then you need to have completed any necessary pre-requisite courses as well.

Application guidance

For your visiting student application you should indicate a preference for either courses offered in the 2nd year, called Part A, or if you have sufficient academic background in these subjects (the equivalent of the 2nd year of the Oxford degree) then you could focus on 3rd Year courses, Part B. Mixing courses between the years cannot be accommodated due to timetable clashes and participation in practical labs is not possible.

For your academic work submission please send appropriate problems and solutions and/or essay-based academic work you have submitted for previous physics courses, this should include any grade and/or comments. Please do not submit lab reports.

Physics courses available 2026-27

2nd Year Courses taught in Michaelmas term

- **Mathematical Methods**

Matrices and linear transformations, including translations and rotations in three dimensions and Lorentz transformations in four dimensions. Eigenvalues and eigenvectors of real symmetric matrices and of Hermitian matrices. Diagonalization of real symmetric matrices; diagonalization of Hermitian matrices. The method of separation of variables in linear partial differential equations in two, three and four variables; and for problems with spherical and planar symmetry. Use of Cartesian, spherical polar and cylindrical polar coordinates (proofs of the form of D2will not be required). Eigenvalues and eigenfunctions of second-order linear ordinary differential equations of the Sturm–Liouville type; orthogonality of eigenfunctions belonging to different eigenvalues; simple eigenfunction expansions including Fourier series. Fourier transform, its inverse, and the convolution theorem. Concept and use of the delta function. Solution by separation of variables for problems with spherical and planar symmetry. Steady-state problems, initial-value problems.

- **A1. Thermal Physics (some taught in Hilary term)**

Kinetic Theory

Maxwell distribution of velocities: derivation assuming the Boltzmann factor, calculation of averages, experimental verification. Derivation of pressure and effusion formulae, distribution of velocities in an effusing beam, simple kinetic theory expressions for mean free path, thermal conductivity and viscosity; dependence on temperature and pressure, limits of validity. Practical applications of kinetic theory.

Heat transport

Conduction, radiation and convection as heat-transport mechanisms. The approximation that heat flux is proportional to the temperature gradient. Derivation of the heat diffusion equation. Generalization to systems in which heat is generated at a steady rate per unit volume. Problems involving sinusoidally varying surface temperatures.

Thermodynamics

Zeroth & first laws. Heat, work and internal energy: the concept of a function of state. Slow changes and the connection with statistical mechanics: entropy and pressure as functions of state. Heat engines: Kelvin's statement of the second law of thermodynamics and the equivalence and superiority of reversible engines. The significance of ∫dQ/T=0 and the fact that entropy is a function of state. Practical realization of the thermodynamic temperature scale. Entropy as dQ (reversible)/T. Enthalpy, Helmholtz energy and Gibbs energy as functions of state. Maxwell relations. Concept of the equation of state; thermodynamic implications. Ideal gas, van der Waals gas. Reversible and free expansion of gas; changes in internal energy and entropy in ideal and non-ideal cases. Joule–Kelvin expansion; inversion temperature and microscopic reason for cooling. Impossibility of global entropy decreasing: connection to latent heat in phase changes. [Non-examinable: Constancy of global entropy during fluctuations around equilibrium.] Chemical potential and its relation to Gibbs energy. Equality of chemical potential between phases in equilibrium. Latent heat and the concepts of first-order and continuous phase changes. Clausius–Clapeyron equation and simple applications. Simple practical examples of the use of thermodynamics.

Statistical mechanics

Boltzmann factor. Partition function and its relation to internal energy, entropy, Helmholtz energy, heat capacities and equations of state. [Non-examinable: Quantum states and the Gibbs hypothesis.] Density of states; application to: the spin-half paramagnet; simple harmonic oscillator (Einstein model of a solid); perfect gas; vibrational excitations of a diatomic gas; rotational excitations of a heteronuclear diatomic gas. Equipartition of energy. Bosons and fermions: Fermi–Dirac and Bose– Einstein distribution functions for non-interacting, indistinguishable particles. Simple treatment of the partition function for bosons and fermions when the particle number is not restricted and when it is: microcanonical, canonical and grand canonical ensemble. Chemical potential. High-temperature limit and the Maxwell–Boltzmann distribution. [Non-examinable: Simple treatment of fluctuations.] Low-temperature limit for fermions: Fermi energy and low-temperature limit of the heat capacity; application to electrons in metals and degenerate stars. Low-temperature limit for boson gas: Bose– Einstein condensation: calculation of the critical temperature of the phase transition; heat capacity; relevance to superfluidity in helium. The photon gas: Planck distribution, Stefan–Boltzmann law. [Non-examinable: Kirchhoff's law.]

- **A2. Electromagnetism**

Electromagnetic waves in free space. Derivation of expressions for the energy density and energy flux (Poynting vector) in an electromagnetic field. Radiation pressure.

Magnetic vector potential. [Non-examinable: The change of E and B fields under Lorentz transformations in simple cases.]

Dielectric media, polarisation density and the electric displacement D. Dielectric permittivity and susceptibility. Boundary conditions on E and D at an interface between two dielectrics. Magnetic media, magnetisation density and the magnetic field strength H. Magnetic permeability and susceptibility; properties of magnetic materials as represented by hysteresis curves. Boundary conditions on B and H at an interface between two magnetic media. Maxwell's equations in the presence of dielectric and magnetic media.

Electromagnetic wave equation in dielectrics: refractive index and impedance of the medium. Reflection and transmission of light at a plane interface between two dielectric media. Brewster angle. Total internal reflection. [Non- examinable: Fresnel equations] The electromagnetic wave equation in a conductor: skin depth. Electromagnetic waves in a plasma; the plasma frequency. Dispersion and absorption of electromagnetic waves, treated in terms of the response of a damped classical harmonic oscillator.

Treatment of electrostatic problems by solution of Poisson's equation using separation of variables in Cartesian, cylindrical or spherical coordinate systems.

Theory of a loss-free transmission line: characteristic impedance and wave speed. Reflection and transmission of signals at connections between transmission lines and at loads; impedance matching using a quarter-wavelength transmission line.

[Non-examinable: Rectangular loss-less waveguides and resonators.]

Electronics

Fourier transform of signals (digital). Nyquist theorem. Interpolation and signal reconstruction. Noise (Johnson noise, shot noise, 1/f noise, digitisation noise, interference noise).

2nd Year Courses taught in Hilary term

- **A3. Quantum Physics (teaching begins at the end of Michaelmas term)**

Probabilities and probability amplitudes. Interference, state vectors and the bra-ket notation, wavefunctions. Hermitian operators and physical observables, eigenvalues and expectation values. The effect of measurement on a state; collapse of the wave function. Successive measurements and the uncertainty relations. The relation between simultaneous observables, commutators and complete sets of states.

The time-dependent Schroedinger equation. Energy eigenstates and the time-independent Schroedinger equation. The time evolution of a system not in an energy eigenstate. Wave packets in position and momentum space.

Probability current density.

Wave function of a free particle and its relation to de Broglie's hypothesis and Planck's relation. Particle in one-dimensional square-well potentials of finite and infinite depth. Scattering off, and tunnelling through, a one-dimensional square potential barrier. Circumstances in which a change in potential can be idealised as steep; [Non examinable: Use of the WKB approximation.]

The simple harmonic oscillator in one dimension by operator methods. Derivation of energy eigenvalues and eigenfunctions and explicit forms of the eigenfunctions for n=0,1 states.

Amplitudes and wave functions for a system of two particles. Simple examples of entanglement.

Commutation rules for angular momentum operators including raising and lowering operators, their eigenvalues (general derivation of the eigenvalues of L2and Lz not required), and explicit form of the spherical harmonics for l=0,1 states. Rotational spectra of simple diatomic molecules.

Representation of spin-1/2 operators by Pauli matrices. The magnetic moment of the electron and precession in a homogeneous magnetic field. The Stern–Gerlach experiment. The combination of two spin-1/2 states into S=0,1; [non-examinable: Derivation of states of well-defined total angular momentum using raising and lowering operators]. Rules for combining angular momenta in general (derivation not required). [Non-examinable: term symbols.]

Hamiltonian for the gross structure of the hydrogen atom. Centre of mass motion and reduced particle. Separation of the kinetic-energy operator into radial and angular parts. Derivation of the allowed energies; principal and orbital angular-momentum quantum numbers; degeneracy of energy levels.

Functional forms and physical interpretation of the wavefunctions for n<3.

First-order time-independent perturbation theory, both non-degenerate and degenerate (questions will be restricted to systems where the solution of the characteristic equation can be obtained by elementary means). Interaction of a hydrogen atom with a strong uniform external magnetic field. The linear and quadratic Stark effects in hydrogen.

Exchange symmetry for systems with identical fermions or bosons; derivation of the Pauli principle. Gross-structure Hamiltonian of helium. Implications of exchange symmetry for wavefunctions of stationary states of helium; singlet and triplet states. Estimation of the energies of the lowest few states using hydrogenic wavefunctions and perturbation theory.

The variational method for ground-state energies; application to helium.

The adiabatic and sudden approximations with simple applications.

Time-dependent perturbation theory. The interaction of a hydrogen atom with an oscillating external electric field; dipole matrix elements, selection rules and the connection to angular-momentum conservation. Transition to a continuum; density of states, Fermi's golden rule.

[Non-examinable -Classical uncertainty in quantum mechanics: pure and impure states. The density matrix and trace rules. Time-evolution of the density matrix. Measurement and loss of coherence.]

- **Optics**

Diffraction, and interference by division of wave front (quasi-monochromatic light). Questions on diffraction will be limited to the Fraunhofer case. Statement of the Fraunhofer condition. Practical importance of Fraunhofer diffraction and experimental arrangements for its observation. Derivation of patterns for multiple slits and the rectangular aperture using Huygens-Fresnel theory with a scalar amplitude and neglecting obliquity factors. (The assumptions involved in this theory will not be asked for.) The resolving power of a telescope. Fourier transforms in Fraunhofer diffraction: the decomposition of a screen transmission function with simple periodic structure into its spatial frequency components. Spatial filtering. The resolving power of a microscope with coherent illumination. Transverse and temporal coherence.

Interference by division of amplitude (quasi-monochromatic light). Two-beam interference, restricted to the limiting cases of fringes of equal thickness and of equal inclination. Importance in modern optical and photonic devices as illustrated by: the Michelson interferometer (including its use as a Fourier-transform spectrometer); the Fabry–Perot etalon (derivation of the pattern, definition of finesse).

Distinction between completely polarized, partially polarized and unpolarized light. Phenomenological understanding of birefringence; principles of the use of uniaxial crystals in practical polarizers and wave plates (detailed knowledge of individual devices will not be required). Production and analysis of completely polarized light. Practical applications of polarized light.

Basic principles of lasers and laser action: population inversion, Einstein coefficients, pumping; coherence length, as measured using the Michelson Interferometer.

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3rd Year courses taught in Michaelmas term

- **B2. Symmetry and Relativity**

Concept of symmetry, groups and representations. Examples of symmetries and applications. Relativity in four-vector form and Lorentz transformations (Lorentz group), including Compton scattering and application to formation, collision, annihilation, and decay of particles. Four-forces and simple motion problems. Electromagnetism in four-vector and tensor formulation, including the Maxwell field tensor, the energy-momentum tensor of the electromagnetic fields, and their transformations. Relativistic electrodynamics and radiation (field of an accelerated charge, retarded potentials, radiated power and Larmor's formula). Concept of gauge invariance.

- **B4. Nuclear and Particle Physics**

Knowledge of the special relativity in the Prelims paper CP1 will be assumed

Scattering in quantum mechanics to first order, concept of a scattering cross section, form factors, propagators, virtual particle exchange. Resonant scattering, decay widths, Breit-Wigner formula. Nuclear mass, binding energy, the semi-empirical mass formula, stability, radioactivity, alpha and beta decay. Basic fission and fusion reactions. Quark model of hadrons: the light meson and baryon multiplets and quarkonium. The Standard Model: quark and lepton families, fundamental interactions, Cabibbo mixing. Strong interaction, a qualitative discussion of confinement, the concept of colour. Weak interaction, parity violation, properties and decays of the W and Z bosons.

- **B6. Condensed Matter Physics**

Structure and types of condensed matter. Chemical Bonding. Crystal structure: lattices, unit cells and basis, reciprocal lattices, Brillouin zones. X-ray and neutron diffraction: Bragg and Laue equations, structure factor, atomic form factor and nuclear scattering length. Vibrations in lattices: monatomic and diatomic chains, phonons, heat capacity, Einstein and Debye models. Free-electron theory of metals: Fermi energy and Fermi surface, density of states in 1, 2, and 3 dimensions, heat capacity, electrical conductivity. Band structure: nearly free electron model for electron dispersion in a periodic potential, tight binding model, band gaps, distinction between metals, semiconductors and insulators. Direct and indirect gap semiconductors, optical absorption, donor and acceptor impurity doping. Mobility and Hall effect, temperature dependence of carrier concentration. Magnetic properties of matter: diamagnetism, paramagnetism and Hund's rules, Pauli paramagnetism, exchange interactions, ferromagnetism and Curie-Weiss law, domains.

3rd Year courses taught in Hilary term

- **B5. General Relativity**

Gravity as a geometric concept, equivalence principle, tensor formulation of special relativity. Gravitational redshift. Tensor calculus, general covariance, affine connection, metric tensor, covariant derivatives. Newtonian limit/gravitational redshift connection. Parallel transport. Geodesic motion in covariant form. Riemann and Ricci curvature tensors. Bianchi identities and Einstein Field Equations. Classical tests of GR: light deflection, advance of Mercury's perihelion, Shapiro delay. Black holes via Schwarzschild solution. Stellar hydrodynamic equilibrium. Simple treatment of gravitational radiation. Binary orbit decay by gravity wave emission. Detections of gravitational waves. Expanding universe dynamics. FRW metric. Accelerating universe, cosmological constant as vacuum energy.

- **B1. Fluids**

Fundamental definitions, conservation principles. Eulerian and Lagrangian descriptions. Ideal fluids: Euler and vorticity equations, Bernoulli theorem (steady flow). Surface waves: dispersion relation, group velocity, gravity-capillary waves. Sound waves (linear treatment). Potential flows, irrotational flow past an obstacle: complex potential, Kutta-Joukowski lift theorem. Concept of stress in a continuous medium, stress-strain relationship. Viscous flows: Navier-Stokes equation, no-slip condition, Reynolds number, examples of elementary viscous flows, dynamical similarity, very viscous flows. Instabilities: Kelvin-Helmholtz, Rayleigh-Bénard, Rayleigh-Taylor; transition to turbulence. Boundary layers: 2D laminar boundary layer equations, boundary layer separation. Stratified fluids: buoyancy, internal gravity waves.

- **B3. Atomic and Laser Physics**

Multi-electron atoms: central field approximation, electron configurations, shell structure, residual electrostatic interaction, spin orbit coupling (fine structure). Spectra and energy levels: Term symbols, selection rules, X-ray notation, Auger transitions. Hyperfine structure; effects of magnetic fields on fine and hyperfine structure. Two level system in a classical light field: Rabi oscillations and Ramsey fringes, echoes, atomic clocks, decaying states; Einstein A and B coefficients; homogeneous and inhomogeneous broadening of spectral lines; rate equations. Optical absorption and gain, radiation transport: population inversion in 3- and 4-level systems; optical cross sections; saturated absorption and gain.