

# Physics (PHYS)

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## Physics (PHYS) Courses

### PHYS 1001 [0.5 credit]

#### Foundations of Physics I

This calculus-based course on classical mechanics covers kinematics, dynamics, gravitation, and oscillatory motion. This is a specialist course for students intending to take further courses in physics.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1002, BIT 1203, PHYS 1003, PHYS 1007, PHYS 1107.

Prerequisite(s): Grade 12 Mathematics: Advanced Functions and Grade 12 Mathematics: Calculus and Vectors or equivalent, plus one of MATH 1004 or MATH 1052 (the MATH course may be taken concurrently); or permission of the Physics Department. Grade 12 Physics is strongly recommended.

Lectures three hours a week, laboratory or tutorial three hours a week.

### PHYS 1002 [0.5 credit]

#### Foundations of Physics II

An introduction to electricity, magnetism, electromagnetic fields, and wave motion. This is a specialist course for students intending to take further courses in physics.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1004, PHYS 1008, PHYS 1108.

Prerequisite(s): PHYS 1001, or PHYS 1003, or PHYS 1007 with a grade of B-; MATH 1004 or MATH 2052 (may be taken concurrently); or permission of the Department.

Lectures three hours a week, laboratory or tutorial three hours a week.

### PHYS 1003 [0.5 credit]

#### Introductory Mechanics and Thermodynamics

Mechanics, gravitation, oscillations, and thermodynamics.

The application of calculus to solve problems in these areas of physics is introduced. This course is intended for students in the physical sciences and engineering.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1002, BIT 1203, PHYS 1001, PHYS 1007, PHYS 1107.

Prerequisite(s): Grade 12 Physics or equivalent, plus Grade 12 Mathematics: Advanced Functions or equivalent, plus one of MATH 1004 or MATH 1052 (the MATH course may be taken concurrently). Note that Grade 12 Mathematics: Calculus and Vectors is strongly recommended.

Lectures three hours a week, laboratory or tutorial three hours a week.

### PHYS 1004 [0.5 credit]

#### Introductory Electromagnetism and Wave Motion

This calculus-based course introduces potential energy, work, electricity, magnetism, oscillations and waves.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1002, PHYS 1008, PHYS 1108.

Prerequisite(s): MATH 1004, ECOR 1101 or ECOR 1053 or (ECOR 1045 and ECOR 1048) or (ECOR 1033 and ECOR 1034)(the ECOR courses may be taken concurrently) or PHYS 1001 or PHYS 1003 or PHYS 1007 (a grade of at least B- is required for PHYS 1007), or permission of the Department.

Lectures three hours a week, laboratory or tutorial three hours a week.

### PHYS 1007 [0.5 credit]

#### Elementary University Physics I

Mechanics, properties of matter, thermodynamics.

Applications chosen in part from the life sciences. For students who lack the prerequisites for PHYS 1001 or PHYS 1003, or who do not intend to take upper-year courses in physics.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1002, BIT 1203, PHYS 1001, PHYS 1003, PHYS 1107.

Prerequisite(s): (i) Grade 12 Mathematics: Advanced Functions or equivalent, or MATH 0107 (may be taken concurrently); or (ii) Grade 12 Mathematics: Calculus and Vectors or equivalent, or MATH 1007 (may be taken concurrently); or (iii) permission of the Physics Department.

Lectures three hours a week, laboratory or tutorial three hours per week.

### PHYS 1008 [0.5 credit]

#### Elementary University Physics II

Electricity and magnetism, DC and AC circuits, wave motion and light. Elements of modern physics.

Applications chosen in part from the life sciences.

Includes: Experiential Learning Activity

Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1002, PHYS 1004, PHYS 1108.

Prerequisite(s): PHYS 1001 or PHYS 1003 or PHYS 1007.

Lectures three hours a week, laboratory or tutorial three hours per week.

**PHYS 1107 [0.5 credit]****Introductory University Physics I**

Mechanics, properties of matter, thermodynamics. Applications chosen in part from the life sciences. For students who lack the prerequisites for PHYS 1001 or PHYS 1003, or who do not intend to take upper-year courses in physics.

Precludes additional credit for BIT 1002, BIT 1203, PHYS 1001, PHYS 1003, PHYS 1007.

Prerequisite(s): (i) Grade 12 Mathematics: Advanced Functions or equivalent, or MATH 0107 (may be taken concurrently); or (ii) Grade 12 Mathematics: Calculus and Vectors or equivalent, or MATH 1007 (may be taken concurrently); or (iii) permission of the Physics Department.

Lectures three hours a week.

**PHYS 1108 [0.5 credit]****Introductory University Physics II**

Electricity and magnetism, DC and AC circuits, wave motion and light. Elements of modern physics. Applications chosen in part from the life sciences.

Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1002, PHYS 1004, PHYS 1008.

Prerequisite(s): PHYS 1001 or PHYS 1003 or PHYS 1007 or PHYS 1107.

Lectures three hours a week.

**PHYS 1901 [0.5 credit]****Planetary Astronomy**

Description of the known stellar, galactic and extra-galactic systems together with the instruments used to study them. Modern ideas concerning the structure, origin and evolution of our own planet. Formation of the Moon - Earth system. Study of the planets in our solar system.

Precludes additional credit for PHYS 2203.

Lectures two and one-half hours a week.

**PHYS 1902 [0.5 credit]****From our Star to the Cosmos**

Starting with the Sun, the course studies its composition and source of power, then compares our Sun with the other stars in the galaxy and beyond. Modern ideas concerning the structure, origin and evolution of the universe, pulsars and supernovae are examined.

Precludes additional credit for PHYS 2203.

Lectures two and one-half hours a week.

**PHYS 1905 [0.5 credit]****Physics Behind Everyday Life**

Examination of the physics behind everyday life. Topics may include transportation, sports, weather and climate, electricity, and sustainable energy. No science background is required. Faculty of Science students may only take this course as a free elective.

Includes: Experiential Learning Activity

Online Course.

**PHYS 2004 [0.5 credit]****Modern Physics for Engineers**

Introduction to aspects of modern physics relevant to engineering. Thermal radiation. Concepts of relativistic kinematics. Wave-particle duality. Photoelectric effect, Compton scattering. Bohr theory of the hydrogen atom. Optical and x-ray spectra, lasers. Nuclear physics and applications.

Precludes additional credit for PHYS 2604 and PHYS 2605.

Prerequisite(s): PHYS 1002 or PHYS 1004 or PHYS 1008 with a grade of B- or better, plus MATH 1004 and MATH 1104 or equivalent. Restricted to B.Eng. students not in the Engineering Physics program. Students in programs other than B.Eng. must obtain permission of the Department.

Lectures three hours a week.

**PHYS 2007 [0.5 credit]****Second Year Physics Laboratory: Selected Experiments and Seminars**

Students complete a number of experiments selected from classical physics and geometric optics, modern physics, etc. Seminars on relevant experimental topics will be included. Includes: Experiential Learning Activity.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 1002, or PHYS 1004 (PHYS 1008 is also acceptable provided a minimum average grade of B- is presented).

Six hours a week.

**PHYS 2101 [0.5 credit]****Mechanics and Properties of Matter**

Equations of motion for a single particle. Harmonic oscillation. Noninertial reference frames. Orbits in a central force field. Motion of systems of particles and of rigid bodies. Introduction to special relativity. Laboratory experiments in classical mechanics and properties of matter.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall average of B- or better or MATH 1004 and MATH 1104.

Lectures three hours a week, laboratory three hours a week, tutorials (optional) once a week.

**PHYS 2202 [0.5 credit]****Wave Motion and Optics**

Geometrical optics. Types of waves, vibrating string and the classical wave equation. General solutions for traveling waves. Superposition and interference, coherence, wave packets, waves in 2 and 3 dimensions. Propagation of electromagnetic waves. Light and physical optics, oscillator model for dispersion, diffraction, polarization, and refraction.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1104 or MATH 2152, and MATH 2004 or MATH 2000 (MATH 2000 may be taken concurrently).

Lectures three hours a week, laboratory three hours a week.

**PHYS 2203 [0.5 credit]****Astronomy**

The observational basis of astronomy. The history of astronomy, properties of light, solar system observations and stellar astronomy.

Precludes additional credit for PHYS 1901 and PHYS 1902.

Prerequisite(s): PHYS 1002 or PHYS 1004 or permission of the department. PHYS 1008 with a grade of B- or better may also be used if MATH 1004 or MATH 1007 or MATH 2052 have been successfully completed.

Lectures three hours a week.

**PHYS 2212 [0.5 credit]****Wave Mechanics and Thermodynamics**

Types of waves and the classical wave equation, wave functions in 2 and 3 dimensions, reflection and refraction, superposition of waves, polarization, interference, diffraction, coherence, wave packets. Temperature and thermodynamic equilibrium, heat, work and first law of thermodynamics, entropy and second law of thermodynamics.

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1004 and MATH 1104 or MATH 2152, and MATH 2004 or MATH 2000 (MATH 2000 or MATH 2004 may be taken concurrently).

Lectures three hours a week

**PHYS 2305 [0.5 credit]****Electricity and Magnetism**

Electrostatic field and potential, Gauss' law. Properties of conductors. Magnetic effects from currents. Motion of charges in electric and magnetic fields. Energy in electric and magnetic fields. Electromagnetic induction. Maxwell's equations in vacuum using vector differential and integral calculus.

Prerequisite(s): PHYS 1001, PHYS 1002, or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall grade of B- or higher; MATH 2004 or MATH 2000 (MATH 2000 may be taken concurrently). Lectures three hours a week.

**PHYS 2306 [0.5 credit]****Physics of Electrical and Electronic Measurements I**

D.C. and A.C. circuit theory. Resonant circuits. Basic measuring devices, the oscilloscope; impedances, bandwidth, noise; vacuum tubes, transistors, useful approximations for circuit design; feedback, amplifiers, oscillators; operational circuits; digital circuits. Lectures emphasize the physical basis of instrument design.

Laboratory emphasizes modern digital instrumentation.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 1001, PHYS 1002 or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall grade of B- or better.

Lectures three hours a week, laboratory three hours a week.

**PHYS 2401 [0.5 credit]****Thermal Physics**

Introduction to thermodynamics and statistical mechanics. Temperature and thermodynamic equilibrium. Work, internal energy and heat; first law. Kinetic theory of gases. Basic probability theory. Microscopic states and entropy. Absolute temperature, reversibility and the second law of thermodynamics. Thermodynamic processes and applications.

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004, (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B-); plus MATH 1004 and MATH 1104 or MATH 2052 and MATH 2152.

Lectures three hours a week.

**PHYS 2604 [0.5 credit]****Modern Physics I**

The course is designed to provide a logical transition from classical to modern physics. Special relativity. Rutherford scattering, atomic models. Thermal radiation. Photoelectric effect, Compton scattering. Bohr theory of the hydrogen atom. Atomic energy states, optical spectra, lasers. X-rays. Radioactivity. Quantum Mechanics.

Includes: Experiential Learning Activity

Precludes additional credit for PHYS 2004 and PHYS 2605.

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1004 and MATH 1104, or MATH 2052 and MATH 2152.

Lectures three hours a week, laboratory three hours a week.

**PHYS 2605 [0.5 credit]****Modern Physics I**

The course is designed to provide a logical transition from classical to modern physics. Special relativity. Rutherford scattering, atomic models. Thermal radiation. Photoelectric effect, Compton scattering. Bohr theory of the hydrogen atom. Atomic energy states, optical spectra, lasers. X-rays. Radioactivity.

Precludes additional credit for PHYS 2004 and PHYS 2604.

Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1004 and MATH 1104, or MATH 2052 and MATH 2152.

Lecture 3 hours per week.

**PHYS 2801 [0.5 credit]****Computational Methods in Physics**

Introduction to computational methods in physics. Software platforms and programming languages. Data formats and structures, histograms, and data visualization. Probability distributions, fitting/parameter estimation, function minimization. Interpretation and treatment of uncertainties. Introduction to machine learning and classification.

Prerequisite(s): PHYS 1001 or PHYS 1003 or PHYS 1007, and COMP 1005.

Lectures three hours a week.

**PHYS 2903 [0.5 credit]****Physics Towards the Future**

From classical phenomena to aspects of modern physics and recent advances. Topics may include light and colour, music and sound, cell phones, the galaxy and beyond.

No science background is required. Faculty of Science students may only take this course as a free elective.

Includes: Experiential Learning Activity

Prerequisite(s): second-year standing.

Online course.

**PHYS 3007 [0.5 credit]****Third Year Physics Laboratory: Selected Experiments and Seminars**

Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.

Includes: Experiential Learning Activity

Precludes additional credit for PHYS 3008, PHYS 3009.

Prerequisite(s): PHYS 2007 or (PHYS 2202 and PHYS 2604) or permission of the Department.

Six hours a week.

**PHYS 3008 [0.5 credit]****Third Year Physics Laboratory: Selected Experiments and Workshop**

Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. Instruction on instrumentation building techniques will be given.

Includes: Experiential Learning Activity

Precludes additional credit for PHYS 3007, PHYS 3009.

Prerequisite(s): PHYS 2007 or (PHYS 2202 and PHYS 2604) or permission of the department.

Six hours a week.

**PHYS 3009 [0.5 credit]****Third Year Physics Laboratory: Selected Experiments and Seminars with Observational Astronomy**

Students complete a small number of experiments selected from astronomy, astrophysics, modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. At least one astronomy/astrophysics related experiment is required. An exercise on literature searches and student seminars on experimental and numerical methods are included.

Includes: Experiential Learning Activity

Precludes additional credit for PHYS 3007, PHYS 3008.

Prerequisite(s): PHYS 2007 or (PHYS 2202 and PHYS 2604), and PHYS 2203, or permission of the Department.

Six hours a week.

**PHYS 3207 [0.5 credit]****Topics in Biophysics**

Introduction to biophysics. Random motion of molecules and diffusion; viscosity and the circulatory system; laws of thermodynamics and physical forces responsible for chemical reactions, molecular self-assembly and recognition; enzyme kinetics and molecular machines; nerve impulse and its propagation.

Prerequisite(s): PHYS 2212 or PHYS 2604, or permission of the Department.

Lectures three hours a week, tutorial or seminar one hour a week.

**PHYS 3308 [0.5 credit]****Electromagnetism**

Electrostatics field and magnetostatics in the presence of matter. Solving Laplace's and Poisson's equations.

Multipole expansions. Vector potential. Faraday's laws of induction; Maxwell's equations in matter. Waves in vacuum and dielectric media, guided waves.

Precludes additional credit for ELEC 3909.

Prerequisite(s): PHYS 2305, MATH 2004 or MATH 2008, and MATH 3705, or permission of the Department.

Lectures three hours a week.

**PHYS 3402 [0.5 credit]****Heat and Thermodynamics**

Zeroth, First, Second and Third Laws of

Thermodynamics; enthalpy, Helmholtz and Gibbs functions and the Maxwell relations; phase transitions; thermodynamics of magnetism; cryogenics cooling by Joule-Thompson effect, adiabatic expansion of a gas, adiabatic demagnetization, helium dilution refrigeration; black body radiation; negative temperatures.

Prerequisite(s): PHYS 2101 and PHYS 2305, MATH 2007, MATH 2008, MATH 2107 and MATH 2401 or permission of the Department.

Lectures three hours a week.

**PHYS 3606 [0.5 credit]****Modern Physics II**

Elements of condensed matter physics, semiconductors, superconductivity. Elements of nuclear physics, fission, fusion, power generation. Introduction to particle physics. Ionizing radiation: production, interactions, detection. Medical physics: radiation biophysics, cancer therapy, imaging.

Includes: Experiential Learning Activity

Also listed as PHYS 3608.

Prerequisite(s): PHYS 2007 and PHYS 2605, or PHYS 2604, and PHYS 3701, or permission of the Department.

Lectures three hours a week, laboratory two hours a week.

**PHYS 3608 [0.5 credit]****Modern Applied Physics**

Elements of condensed matter physics, semiconductors, superconductivity. Modern optics. Elements of nuclear physics, fission, fusion, power generation. Ionizing radiation: production, interactions, detection. Medical physics: radiation biophysics, cancer therapy, imaging. Includes: Experiential Learning Activity

Also listed as PHYS 3606.

Prerequisite(s): PHYS 2007 and PHYS 2605, or PHYS 2604, and PHYS 3701, or permission of the Department.

Lectures three hours a week, laboratory three hours a week.

**PHYS 3701 [0.5 credit]****Elements of Quantum Mechanics**

Analysis of interference experiments with waves and particles; fundamental concepts of quantum mechanics, Schrödinger equation; angular momentum, atomic beams; hydrogen atom; atomic and molecular spectroscopy; Pauli principle; simple applications in the physics of elementary particles.

Precludes additional credit for PHYS 3705.

Prerequisite(s): PHYS 2605 or PHYS 2604, MATH 2000 [1.0] (may be taken concurrently), or MATH 2004 or MATH 2008, and MATH 3705 (may be taken concurrently), or permission of the Department.

Lectures three hours a week.

**PHYS 3705 [0.5 credit]****Introduction to Quantum Systems**

This course is aimed at Computer Science and other students interested in developing a foundational understanding of quantum systems. Topics include: postulates of quantum mechanics, Hilbert space and observables, qubits, 2 state systems, entanglement, Schrodinger equation, 1D potentials, tunnelling, EPR paradox.

Precludes additional credit for PHYS 3701.

Prerequisite(s): (MATH 1004 or MATH 1007) and (MATH 1104 or MATH 1107).

Lectures three hours a week

**PHYS 3801 [0.5 credit]****Classical Mechanics**

Introduction to Lagrangian and Hamiltonian mechanics: Poisson brackets, tensors and dyadics; rigid body rotations: introductory fluid mechanics coupled systems and normal coordinates; relativistic dynamics.

Prerequisite(s): PHYS 2101, PHYS 2202, PHYS 2305, MATH 2007, MATH 2008, MATH 2107, MATH 2401 or permission of the Department.

Lectures three hours a week.

**PHYS 3802 [0.5 credit]****Advanced Dynamics**

Equations of motion for a single particle. Oscillatory Motion. Lagrangian and Hamiltonian formulations of mechanics. Central force motion. Motion of systems of particles and of rigid bodies.

Prerequisite(s): PHYS 2305 and MATH 2004, or permission of the Department.

Lectures three hours a week.

**PHYS 3807 [0.5 credit]****Mathematical Physics I**

Boundary Value problems involving curvilinear coordinates; spherical harmonics, Bessel functions, Green's functions. Functions of a complex variable: analytic functions, contour integration, residue calculus. Precludes additional credit for MATH 3007 or MATH 3057.

Prerequisite(s): ELEC 2501 or PHYS 2305, MATH 2004, MATH 3705 or permission of the Department.

Lectures three hours a week, tutorial one hour a week.

**PHYS 3808 [0.5 credit]****Mathematical Physics II**

Solution of second-order total differential equations by Frobenius' method. Sturm-Liouville theory. Special functions: Legendre, Bessel, Hermite, Laguerre and associated functions. Partial differential equations: method of separation of variables, eigenfunctions and eigenvalues and eigenfunction expansions. Green's function techniques for solving inhomogeneous partial differential equations.

Precludes additional credit for MATH 3004, MATH 3008, MATH 3705, and PHYS 3806.

Prerequisite(s): PHYS 3807 or MATH 3007 or permission of the Department.

Lectures three hours a week.

**PHYS 3999 [0.0 credit]****Co-operative Work Term Report**

Provides practical experience for students enrolled in the Co-operative option. Students must receive satisfactory evaluations from their work term employer. Written and oral reports will be required. Graded as Sat or Uns.

Includes: Experiential Learning Activity

Prerequisite(s): registration in the Physics Co-operative education option and permission of the Department.

**PHYS 4007 [0.5 credit]****Fourth-Year Physics Laboratory: Selected Experiments and Seminars**

Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 3606 (or PHYS 3608) and registration in the Engineering Physics program.

Laboratory, six hours a week.

**PHYS 4008 [0.5 credit]****Fourth-Year Physics Laboratory: Selected Experiments and Workshop**

Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. Instruction on instrumentation building techniques will be given.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 3007.

Six hours a week.

**PHYS 4201 [0.5 credit]****Astrophysics**

Stellar evolution, including stellar modeling, main sequence stars, red giants and the end states of stars such as neutron stars and black holes. Galactic structure and dynamics. Neutrino astrophysics.

Prerequisite(s): PHYS 3701, PHYS 3606 or PHYS 3608, and PHYS 2401 or PHYS 4409, or permission of the Department. (PHYS 3606 or PHYS 3608 and PHYS 4409 may be taken concurrently).

Also offered at the graduate level, with different requirements, as PHYS 5401, for which additional credit is precluded.

Lectures three hours a week.

**PHYS 4202 [0.5 credit]****Cosmology**

Observational evidence for the Big Bang. Cosmological space-time, expansion dynamics and contents of the universe. Physical processes in the expanding universe, inflation, nucleosynthesis, the cosmic microwave background, dark matter, and dark energy.

Prerequisite(s): PHYS 3701, PHYS 3606 or PHYS 3608, and PHYS 2401 or PHYS 4409, or permission of the Department. (PHYS 3606 or PHYS 3608 and PHYS 4409 may be taken concurrently).

Also offered at the graduate level, with different requirements, as PHYS 5402, for which additional credit is precluded.

Lectures three hours per week.

**PHYS 4203 [0.5 credit]****Physical Applications of Fourier Analysis**

Fourier transform, convolution. Sampling theorem. Applications to imaging: descriptors of spatial resolution, filtering. Correlation, noise power. Discrete Fourier transform, FFT. Filtering of noisy signals. Image reconstruction in computed tomography and magnetic resonance. Laplace transform. Integral transforms, application to boundary value problems. Prerequisite(s): MATH 3705, or permission of the Department. Also offered at the graduate level, with different requirements, as PHYS 5313, for which additional credit is precluded. Lectures three hours a week.

**PHYS 4208 [0.5 credit]****Modern Optics**

Electromagnetic wave propagation; reflection, refraction; Gaussian beams, guided waves. Laser theory: stimulated emission, cavity optics, modes, gain and bandwidth; atomic and molecular lasers. Mode locking, Q switching. Diffraction theory, coherence, Fourier optics, holography, laser applications. Optical communication systems, nonlinear effects: devices, fibre sensors, integrated optics. Prerequisite(s): PHYS 2212 or PHYS 2202, PHYS 3606 (or PHYS 3608), and PHYS 3308 or permission of the Department. Also offered at the graduate level, with different requirements, as PHYS 5318, for which additional credit is precluded. Lectures three hours a week.

**PHYS 4307 [0.5 credit]****Electromagnetic Radiation**

Electromagnetic wave propagation in a vacuum, dielectrics, conductors, and ionized gases, reflection, refraction, polarization at the plane boundary between two media; waveguide and transmission line propagation; dipole and quadrupole radiation fields; antenna systems. Electromagnetic mass, radiation pressure. Tensor notation, transformation of the electromagnetic fields. Prerequisite(s): PHYS 3308, PHYS 3801, PHYS 3807 and PHYS 3808 (except for Mathematics and Physics Double Honours students), or permission of the Department. Lectures three hours a week.

**PHYS 4407 [0.5 credit]****Statistical Physics**

Equilibrium statistical mechanics and its relation to thermodynamics. Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics are derived, and applied in appropriate physical situations. Fluctuations. Kinetics and transport processes, including the Boltzmann transport equation and some of its applications. Prerequisite(s): PHYS 3402, PHYS 2602 or PHYS 3601, PHYS 3701 or PHYS 3602, PHYS 4707 (may be taken concurrently); or permission of the Department. Lectures three hours a week.

**PHYS 4409 [0.5 credit]****Thermodynamics and Statistical Physics**

The three Laws of Thermodynamics, enthalpy, Helmholtz and Gibbs functions. Equilibrium statistical mechanics and its relation to thermodynamics. Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Precludes additional credit for PHYS 3402 and PHYS 4407. Prerequisite(s): PHYS 3701 (may be taken concurrently), MATH 2004 and MATH 3705, or permission of the Department.

**PHYS 4508 [0.5 credit]****Solid State Physics**

An introduction to solid state physics. Topics include crystal structure, phonons and lattice vibrations, conductors, semiconductors, insulators and superconductivity. Prerequisite(s): PHYS 3606 or PHYS 3608, and PHYS 3701, or permission of the Department. Lectures three hours a week.

**PHYS 4602 [0.5 credit]****Physics of Elementary Particles**

Standard Model. Properties of leptons, quarks, hadrons. Fundamental interactions: photon, gluons, W/Z bosons. Higgs boson. Conservation laws, invariance principles, quantum numbers. Decay rates and scattering cross-sections. Quantum electrodynamics and chromodynamics. Resonances. Weak interactions, CKM matrix, parity and CP violation. Neutrino masses and oscillations. Future directions. Prerequisite(s): PHYS 4707 or permission of the Department. Also offered at the graduate level, with different requirements, as PHYS 5602, for which additional credit is precluded. Lectures three hours a week.

**PHYS 4608 [0.5 credit]****Nuclear Physics**

Ground state properties of nuclei. Nuclear models, binding energy, properties of excited nuclei. Alpha, beta and gamma decay. Passage of radiation through matter, detectors. Nuclear reactions, cross sections, fission, fusion. Elements of neutron physics.

Prerequisite(s): PHYS 3606 or PHYS 3608 or permission of the Department.

Lectures three hours a week.

**PHYS 4707 [0.5 credit]****Introduction to Quantum Mechanics I**

The basic interpretative postulates of quantum mechanics; applications of wave mechanics and operator methods to various quantum mechanical systems; quantum mechanical treatment of angular momentum.

Prerequisite(s): PHYS 3701 and PHYS 3807 or equivalent, or permission of the Department.

Lectures three hours a week.

**PHYS 4708 [0.5 credit]****Introduction to Quantum Mechanics II**

Scattering theory and application; bound state problems; approximation methods.

Prerequisite(s): PHYS 4707 or permission of the Department.

Lectures three hours a week.

**PHYS 4804 [0.5 credit]****Introduction to General Relativity**

Special relativity using tensor analysis. Curved spacetime with physics applications which may include the solar system, stars, black holes and gravitational waves.

Introduction to differential geometry and Einstein's field equations.

Prerequisite(s): PHYS 3802 or equivalent, or permission of the Department.

Also offered at the graduate level, with different requirements, as PHYS 5804, for which additional credit is precluded.

Lectures three hours a week.

**PHYS 4807 [0.5 credit]****Statistical Data Analysis Techniques for Physics**

Computational methods used in analysis of experimental data. Introduction to probability and random variables. Monte Carlo methods for simulation of random processes. Statistical methods for parameter estimation and hypothesis tests. Confidence intervals. Multivariate data classification. Unfolding methods. Examples primarily from particle and medical physics.

Prerequisite(s): third year standing in a physics program and an ability to program in Python, Java, C or C++, and permission of the Department.

Also offered at the graduate level, with different requirements, as PHYS 5002, for which additional credit is precluded.

Lectures three hours a week.

**PHYS 4901 [0.5 credit]****Special Topics in Physics**

Each year, at the direction of the Department, a course on a special topic may be offered.

Prerequisite(s): permission of the Department.

**PHYS 4907 [0.5 credit]****Fourth-Year Project**

Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.

Includes: Experiential Learning Activity

Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.

Project. Fall term only.

**PHYS 4908 [0.5 credit]****Fourth-Year Project**

Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.

Includes: Experiential Learning Activity

Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.

Project. Winter term only.

**PHYS 4909 [1.0 credit]**

**Fourth-Year Project**

Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.

Includes: Experiential Learning Activity

Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.  
Project