Physics & Astronomy

Faculty

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Program Overview

Physics is often regarded as the cornerstone of the Natural Sciences. It encompasses a diverse range of disciplines including astronomy and astrophysics, photonics, electronics, classical and quantum mechanics, statistical mechanics, particle physics, and solid state physics. The BSc Major program provides students with a fundamental understanding of physics. The highest level of specialization at the undergraduate level is the BSc Honours program. It prepares students for direct entry into graduate work in physics (leading to an MSc or PhD degree). Students may be admitted into the Honours program after one year is completed in the Physics Major program.

The Master of Science (MSc) program is designed to give students a much deeper appreciation of physics while at the same time training them to become independent researchers and scientists. Graduate supervision is available in a wide variety of disciplines including astronomy, astrophysics, exoplanetary science, theoretical cosmology and gravitational theory, and particle physics.

First-year Science Core requirements

All Physics students are required to take six course credits of Introductory Physics (PHY 191, PHY 192), six course credits of Introductory Calculus (MAT 191, MAT 192), and six course credits of Introductory Chemistry (CHM 191, CHM 192), normally in their first year. Students with a Québec collegial diploma (DEC)

shall be granted advanced credit for these courses if they have completed the Pure Science program. If any of these equivalent courses were not completed at CEGEP, they must be completed at Bishop's and advanced credits shall be reduced accordingly. Students with a Québec collegial diploma (DEC) may be exempted from MAT 108 (Matrix Algebra) if they obtained high standing in an equivalent course at CEGEP. Students would have to replace this course if they received an exemption.

Humanities requirement

(BSc students only)

Students must complete six course credits of humanities studies, normally in their first year at Bishop's. Students who have a Québec Collegial Diploma (DEC), students admitted as "Mature Students", and 2nd Bachelor's degree students are all exempt from this requirement. The two Humanities optional courses (6 credits) can be selected from any Humanities courses. It is recommended that at least one of these courses be a writing intensive course.

Arts and Science requirement

(BSc students only)

In addition to the Humanities requirement above, all students are required to complete at least three credits in either the Faculty of Humanities or the Faculty of Social Sciences. Students with program combinations which require more than 72 credits are exempt from this requirement.

Please refer to the Natural Sciences Faculty page for information on Faculty Requirements.

Laboratory Courses

(BSc students only)

When any lecture course (e.g., PHY 206) also has an associated laboratory course (e.g. PHL 206), both the lecture and laboratory courses should be taken concurrently. Laboratory credits thus obtained are in addition to the total required lecture credits specified below for the program.

Undergraduate Programs

Physics Honours (120 credits) HONPHY

Entrance Requirements for Honours Program:
A student will normally be admitted to the Honours program after obtaining at least a 70% average on all required second-year (200-level) physics and mathematics courses. In order to complete an Honours degree, a student must normally obtain an average of at least 65% in required physics courses in each academic year.

Requirements:
First year Science core requirements as listed above*. The following courses are also required for the Physics Honours: PHY 101, PHY 206, PHY 207, PHY 208, PHY 270, PHY 315, PHY 316, PHY 317, PHY 318, PHY 319, PHY 320, PHY 321, PHY325, PHY 361, PHY 371, PHY 462, additional 400-level or 500-level course, PHY 480; MAT 108, MAT 206, MAT 207, MAT 209, MAT 317; CS 211.

Total: **57** lecture-course credits physics, **15** credits math,
3 credits computer science,
15 elective credits = 90 lecture course credits.

Physics labs: PHL 206, PHL 385, PHL 386,
Computer Science lab : CSL 211
Total of 6 lab-course credits.

N.B.: When any lecture course (e.g., PHY 206) also has an associated laboratory course (e.g. PHL 206), both the lecture and laboratory courses must be taken concurrently. Laboratory credits thus obtained are in addition to the total required lecture credits specified above for the program.

**Students with a CEGEP DEC or mature students will be granted advanced credits for these courses as appropriate.*

Physics Major (120 credits) MAJPHY

A Physics Major is less intensive than the Honours program and does not require any 400-level physics courses or MAT 317.

Requirements:
First-year Science core requirements as listed above*. The following courses are also required for the Physics Major:

PHY 101, PHY 206, PHY 207, PHY 208, PHY 270, PHY 315, PHY 316, PHY 317, PHY 318, PHY 319, PHY 320, PHY 321, PHY 325, PHY 361, PHY 371; MAT 108, MAT 206, MAT 207, MAT 209; CS 211.

Total: **45** lecture-course credits physics, **12** credits math,
3 credits computer science, **30** elective credits =
90 lecture course credits.
Physics labs: PHL 206, PHL 385, PHL 386,
Computer Science lab : CSL 211
Total of **6 lab-course credits**.

N.B.: When any lecture course (e.g., PHY 206) also has an associated laboratory course (e.g., PHL 206), both the lecture and laboratory courses must be taken concurrently. Laboratory credits thus obtained are in addition to the total required lecture credits specified above for the program.

**Students with a CEGEP DEC or mature students will be granted advanced credits for these courses as appropriate.*

Physics Minor (24 credits) MINPHY

A minor in Physics allows students to gain a solid introduction to the subject.

Requirements:

The following courses are required:

PHY 191, PHY 192, MAT 108, PHY 101, PHY 206, PHY 207, PHY 208 and one other lecture course in Physics selected from 200 and 300 level courses. The total course credit requirement for the minor is **24 lecture-course credits.**

N.B.: When any lecture course (e.g., PHY 206) also has an associated laboratory course (e.g. PHL 206), both the lecture and laboratory courses must be taken concurrently. Laboratory credits thus obtained are in addition to the total required lecture credits specified above for the program.

PHYSICS HONOURS DEGREE

Two possible sequences are suggested below

	SEQUENCE #1		SEQUENCE #2	
Year/Semester	**FALL**	**WINTER**	**FALL**	**WINTER**
U1	First-year science core credits **OR** DEC in Pure or Applied Science			
U2	PHY 101 PHY 206 / PHL 206 PHY 270 MAT 108 MAT 206	PHY 208 PHY 207 MAT 207 MAT 209 Option 1*	PHY 101 PHY 206 / PHL 206 PHY 270 MAT 108 MAT 206	PHY 208 PHY 207 MAT 207 MAT 209 Option 1*
U3	PHY 318 PHY 361 CS 211 / CSL 211 Option 2* Option 4*	PHY 317 PHY 315 PHY 462 PHY 325 Option 3* Option 5*	MAT 317 PHY 320 PHY 316 CS 211 / CSL 211 PHL 385‡ Option 2*	PHY 321 PHY 319 PHY 371 PHY 466† PHL 386‡ Option 4*
U4	MAT 317 PHY 320 PHY 316 PHY 480 PHL 385‡ …	PHY 321 PHY 319 PHY 371 PHY 466† PHY 480 PHL 386‡	PHY 318 PHY 361 PHY 480 Option 3*	PHY 317 PHY 315 PHY 462 PHY 480 PHY 325 Option 5*

† Or another 400-level course. Students who have maintained an overall cumulative average of 75% or greater and have completed at least 90 credits may be eligible to register in one other graduate (500-level) course instead with the permission of the student's departmental / program chairperson and instructor of the graduate level course.

‡ One-semester lab course (6 hours per week) worth 2 credits.

* At least 3 credits must be taken in either the Faculty of Humanities or Social Sciences if a student's program combinations require less than 75 lecture credits.

PHYSICS MAJOR DEGREE

Two possible sequences are suggested below

	SEQUENCE #1		SEQUENCE #2	
Year/Semester	**FALL**	**WINTER**	**FALL**	**WINTER**
U1	First-year science core credits **OR** DEC in Pure or Applied Science			
U2	PHY 101 PHY 206 / PHL 206 PHY 270 MAT 108 MAT 206	PHY 208 PHY 207 MAT 207 MAT 209 Option 1*	PHY 101 PHY 206 / PHL 206 PHY 270 MAT 108 MAT 206	PHY 208 PHY 207 MAT 207 MAT 209 Option 1*
U3	PHY 318 PHY 361 CS 211 / CSL 211 Option 2* Option 3*	PHY 317 PHY 315 PHY 325 Option 4* Option 5* Option 6*	PHY 320 PHY 316 CS 211 / CSL 211 PHL 385‡ Option 2* Option 3*	PHY 321 PHY 319 PHY 371 PHL 386‡ Option 4* Option 5*
U4	PHY 320 PHY 316 PHL 385‡ Option 7* Option 8* …….	PHY 321 PHY 319 PHY 371 PHL 386‡ Option 9* Option 10*	PHY 318 PHY 361 Option 6* Option 7* …….	PHY 317 PHY 315 PHY 325 Option 8* Option 9* Option 10*

‡ One-semester lab course (6 hours per week) worth 2 credits.

* At least 3 credits must be taken in either the Faculty of Humanities or Social Sciences if a student's program combinations require less than 75 lecture credits.

Elective Courses (Liberal Science Options)

These courses are open to any students with little or no scientific background.

PHY 111 Physics of Everyday Phenomena
PHY 112 Introduction to Holography
PHY 113 Introduction to Astronomy

Physics Major and Honours Courses

These courses typically numbers that start at 100 and extend to 399.

Note that 3rd and 4th year physics students may take 400-level courses if they have the prerequisites.

Physics Honours Courses

Final-year Honours physics courses have numbers that start with 462 and end at 480.

Graduate Courses

All graduate MSc courses have numbers that start with 500 or above.

List of Courses

PHY 101 Statistical Methods in Experimental Science 3-3-0
This course is specifically designed to meet the needs of students of physics, chemistry, biology, mathematics, and computer science. Topics include: errors of observation, graphical visualization of data; descriptive analysis, elementary probability, permutations and combinations; the binomial, normal and Poisson distributions; random sampling; testing hypotheses, significance levels, confidence limits, large and small sampling methods; regression and correlation; chi-square test; analysis of variance (ANOVA).
Note: In order for students to obtain credit for both PHY 101 and MAT 314, PHY 101 must be taken first or concurrently. Students who are enrolled in, or who have credit for, PMA 260, BMA 141, or EMA 141 may not enrol in this course.

PHY 111 The Physics of Everyday Phenomena 3-3-1
This course is designed to meet the needs of non-science students by providing them with a practical introduction to physics and science as it is applies to everyday life. Students are assumed to have no background in math or science. By allowing students to practice science through practical demonstrations of physical phenomena and engaging in small-group inquiry and discussion, they will learn to think logically when solving problems, enhance their scientific literacy, and develop their physical intuition. Typical questions that will be addressed include: Why is the sky blue? Why purchase a car with an anti-locking brake system (ABS)? Where is lightning most likely to strike and how can you best protect yourself? How do medical scanning procedures such as MRI work? Does a curve ball really curve or is it an optical illusion?
Note: Students enrolled in a program in the Faculty of Natural Sciences and Mathematics cannot use this course for science credits.

PHY 112 / FIN 209 Introduction to Holography 3-3-0
This course is designed to give students an introduction to the principles of laser holography (3-D photography) while at the same time providing them with the opportunity to create holograms in the laboratory. Students are assumed to have no background in mathematics or science. Students will make holograms using single and multiple beam reflection and transmission techniques. Special topics related to the making of rainbow, colour, and other types of holograms will be discussed and attention will be given to the application of this medium as a form of visual expression. In addition students will be able to apply their knowledge to create holograms at home (sandbox holography).
Prerequisite: permission of the instructor.
Note: See FIN 209. Students may not take this course for credit if they have received credit for FIN 209
Students enrolled in a program in the Faculty of Natural Sciences and Mathematics cannot use this course for science credits.

PHY 113 Introduction to Astronomy 3-3-1
An outline of our knowledge of the size, structure, and possible origin of the Universe. Starting with the primitive speculations of the Greeks, the course ends with the theory of the expanding universe and its origin in the -"Big Bang"-.
Prerequisite: Students should have a background in high school mathematics.

PHY 191 Introductory Physics I (Mechanics) 3-3-0
This course is designed to give students an introduction to classical mechanics. Topics that will be covered include statics, particle kinematics in one and two dimensions, particle dynamics and Newton's Laws, conservation of energy and momentum, and rotational kinematics and dynamics.
Prerequisites: MAT 191 and PHL 191 or, PHL 193, or PHY 081, or PHY 083.
This course should be taken concurrently with Physics Lab 191 (PHL 191). This course is for students who lack collegial Physics NYA. Students who have received credit for an equivalent course taken elsewhere may not register for this course. Credit will be given for only one of PHY 191 or PHY 193.

PHL 191 Introductory Physics Laboratory I 1-0-3
A series of experiments in General Physics to complement the material covered in PHY 191.
This course must be taken concurrently with PHY 191. May not be taken for credit if credit has been granted for PHL 193.

PHY 192 Introductory Physics II (Electricity and Magnetism) 3-3-0
This course is designed to give students an introduction to electromagnetism and its applications. Topics that will be covered include Coulomb's Law, electric fields, electric potential, capacitance, direct current circuits, magnetism, electromagnetic induction, alternating current circuits, and electromagnetic waves.
Prerequisite: PHY 191, PHY 193, or the permission of the instructor.
Co-requisites: MAT 192 or MAT 199
This course should be taken concurrently with PHL 192. This course is for students who lack collegial Physics NYB. Students who have received credit for an equivalent course taken elsewhere may not register for this course. Credit will be given for only one of PHY 192 or PHY 194.

PHL 192 Introductory Physics Laboratory II 1-0-3
A series of experiments in general physics to complement the material covered in PHY 192.
This course must be taken concurrently with PHY 192. May not be taken for credit if credit has been granted for PHL 194.

PHY 193 Physics for the Life Sciences I 3-3-0
This course is designed to emphasize topics of particular relevance to the life sciences. Topics that will be covered include: mechanics (statics, kinematics, dynamics, conservation of energy and momentum, rotational motion); fluid dynamics (pressure, elasticity, viscosity, diffusion); and thermodynamics (temperature, heat transport, kinetic theory of gases). Concepts and problem-solving skills are emphasized.
Prerequisites: MAT 191 and PHL 191 or, PHL 193, or PHY 081, or PHY 083.
This course should be taken concurrently with PHL 193. This course is for students who lack collegial Physics NYA.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of PHY 191 or PHY 193.

PHL 193 Physics for the Life Sciences Laboratory I 1-0-3
A series of experiments in college physics to complement the material covered in PHY 193.
This course must be taken concurrently with PHY 193. May not be taken for credit if credit has been granted for PHL 191.

PHY 194 Physics for the Life Sciences II 3-3-0
This course is designed to emphasize topics of particular relevance to the life sciences. Topics that will be covered include: vibrations and waves; sound; electrostatics (charges, electric fields and potential); circuits; magnetism (forces, induction, electromagnetic waves); optics (interference, diffraction, instruments); and modern physics (atoms, radioactivity, MRI, CAT).
Prerequisite: PHY 191 or PHY 193 or the permission of the instructor.
Co-requisites: MAT 192 or MAT 199.
This course should be taken concurrently with PHL 194. This course is for students who lack collegial Physics NYB.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of PHY 192 or PHY 194.

PHL 194 Physics for the Life Sciences Laboratory II 1-0-3
A series of experiments in college physics to complement the material covered in PHY 194.
This course must be taken concurrently with PHY 194. May not be taken for credit if credit has been granted for PHL 192.

PHY 206 Waves, Optics, and Modern Physics 3-3-0
Wave phenomena. Wave and photon theories of light. Huygens' principle and its applications. Geometrical optics.Interference, diffraction and polarization of light. Modern physics, including elementary atomic physics, nuclear physics, and radioactivity.
Prerequisite: PHY 191 or PHY 193.
Co-requisite: PHL 206.

PHL 206 Waves, Optics, and Modern Physics Laboratory 1-0-3
Experiments in geometrical and physical optics, wave motion, and modern physics.
This course must be taken concurrently with PHY 206.

CHM 135 /
PHY 207 Thermal and Fluid Physics 3-3-0
Pressure, hydrostatics, and hydrodynamics. Properties of materials and Young's Modulus. Temperature and heat. Kinetic theory of gases. Energy, work, heat. First, second, and third laws of thermodynamics. Entropy and disorder. Specific heat of solids, black body radiation, statistical thermodynamics involving different distributions and their applications.
Prerequisite: PHY 191 (or equivalent).

PHY 208 Introduction to Mechanics 3-3-0
Statics: equilibrium of bodies subject to many forces. Kinematics; rectilinear, plane, circular, and simple harmonic motion. Dynamics: conservation of mechanical energy and momentum; plane and circular motions of particles; rotation of macroscopic bodies. Non-inertial frames.
Prerequisite: PHY 191 or equivalent and PHY 270 (or equivalent), or permission of the instructor.

PHY 214 Astronomy and Astrophysics 3-3-0
A survey of our understanding of the physical properties of the universe. Topics to be studied include: observational astronomy, stellar evolution, binary stars, white dwarfs, neutron stars, black holes, galaxies, quasars, large scale structure of the universe, and cosmology.
Prerequisite: PHY 191 (or equivalent), MAT 191 (or equivalent), or permission of the instructor.

PHY 270 Ordinary Differential Equations 3-3-0
Techniques for solving first order differential equations and second order linear differential equations. Systems of first order equations. Various applications of differential equations.
Co-requisite: MAT 206.
Note: See MAT 310. Students may not take this course for credit if they have received credit for MAT 310.

PHY 273 Observational Astronomy I 3-3-0
Students will become familiar with modern astronomical techniques through a combination of theoretical and hands-on experience. Techniques covered include CCD observations of stars, planets and galaxies, photometry, and spectroscopy. Students will use the Bishop's 0.45 m telescope to take observations of various targets. Student projects may include: determination of the distances and ages of star clusters; measurements of the variability of stars and quasars; determination of the orbital periods of binary systems; measurements of the mass of Jupiter and galaxies; and determination of the Hubble constant.
Prerequisite: Permission of the Instructor.

PHY 315 Special Relativity 3-3-0
Special Relativity. Lorentz Transformations. The geometry of space-time. Relativistic mechanics of massive and massless particles. Elementary particles.
Co-requisite: PHY 208.
Offered alternate years.

PHY 316 Physical and Contemporary Optics 3-3-0
Wave theory, polarization, interference, diffraction. Basics of coherence theory, lasers, holography. Quantum nature of light.
Prerequisite: PHY 206.
Offered alternate years.

PHY 317 Statistical Mechanics 3-3-0
The statistical definition of entropy and temperature. Statistical Ensembles. The Planck and Maxwell-Boltzmann distributions. The Fermi and Bose distributions. Thermodynamic state functions. Applications of Fermi-Dirac and Bose-Einstein statistics.
Pre or Co-requisite: PHY 207.
Offered alternate years.

PHY 318 Advanced Mechanics 3-3-0
Central forces. Newtonian gravitation: planetary orbits and tides. The Lagrangian and Hamilton's Principle. Liouville's Theorem. Poisson brackets. Hamilton-Jacobi theory. Theory of vibrations and small oscillations (normal modes). Dynamics of macroscopic bodies.
Pre or Co-requisites: PHY 208, PHY 270, or permission of the instructor.
Offered alternate years

PHY 319 Electric Circuits and Electronics 3-3-0
Review of D.C. circuits, Kirchoff's laws, network theorems. Network analysis for A.C. circuits, phasors. Diode circuits and filters. The physical basis of semiconductor devices including semiconductor diodes, junction transistors, and field-effect transistors. The operation of transistor amplifiers, digital electronics, and integrated circuits will also be covered.
Prerequisite: PHY 192 or NYB or permission of instructor.
Note: See CS 379. Students may not take this course for credit if they have received credit for CS 379.

PHY 320 Electromagnetism I 3-3-0
Review of vector calculus. Electrostatics: fields and potentials of point charges, dipoles, and distributed charges; Gauss's theorem; Poisson's and Laplace's equations; dielectrics; capacitance. Current electricity.
Prerequisites: PHY 192, PHY 208, MAT 207.
Offered alternate years.

PHY 321 Electromagnetism II 3-3-0
Magnetic phenomena, magnetic induction, Ampere's Law, and solenoids. Faraday's Law and the displacement current. Magnetic and dielectric materials. Magnetic and electric fields: Maxwell's equations of the electro-magnetic field; plane electromagnetic radiation in dielectrics and conducting media. Radiation and antennae.
Prerequisite: PHY 320.
Offered alternate years.

PHY 325 Computational Physics 3-3-0
A broad range of numerical methods that are commonly used to solve problems in physics will be employed. Examples include ordinary and partial differential equations, linear systems, numerical integration and stochastic methods. We will discuss each algorithm within a physical context that includes classical mechanics, chaotic dynamics, electromagnetism, statistical physics, astrophysics, and quantum systems. Students will use the Python programming language to solve the problems.
Co-requisites: CS 211 and CSL 211
Prerequisites: PHY 208 and PHY 270 (or MAT 310).
Offered alternate years

PHY 335 Environmental Physics 3-3-0
This quantitative, calculus-based, course discusses fundamental environmental problems within a physical context. Topics covered include: the greenhouse effect, blackbody radiation, the ozone problem, mathematical techniques, heat transfer, electricity, the transport of pollutants, plumes, and basic groundwater hydrology.
Prerequisite: PHY 207.

PHY 361 Quantum Mechanics I 3-3-0
Topics to be studied include: foundations of quantum mechanics, angular momentum quantization, the Schroedinger equation, central potentials, one-dimensional systems, and the hydrogen atom.
Prerequisite: PHY 208
Co-requisite: PHY 318, or permission of the instructor.
Offered alternate years.

PHY 371 Mathematical Methods of Physics 3-3-0
Power series solutions for second order equations including the method of Frobenius. Discussion of series solutions in connection with the gamma function and Bessel, Legendre and hypergeometric functions. Elementary trigonometric Fourier series and boundary value problems. Certain partial differential equations of physics.
Prerequisites: MAT 207 and MAT 310 or PHY 270.
Note: See MAT 311. Students may not take this course for credit if they have received credit for MAT 311.

PHY 374 Data Mining for Scientists 4-3-3
Data is now created faster than humans are able to understand it and use it. There may be patterns hiding within this data with potentially useful information. This course will teach students, including Biology and Biochemistry students as well as those from Computer Science, how to discover these patterns for the purpose of solving problems, gaining knowledge, and making predictions. Topics covered in this course include data preparation, clustering, classification, association rules for mining and linear regression. This course includes assignments and a final project where the students are required to perform mining on real datasets drawn from the biological and physical sciences.
Prerequisite: PHY 101 (or equivalent).
Note: See CS 305. Students may not take this course for credit if they have received credit for CS 305.

PHY 376 Calculus of Variations 3-3-0
Euler-Lagrange equations for constrained and unconstrained single and multiple integral variational problems. Parameter-invariant single integrals. General variational formula. The canonical formalism. Hilbert's independent integral. Hamilton-Jacobi equation and the Caratheodory complete figure. Fields and the Legendre and Weierstrass sufficient conditions.
Prerequisite: Permission of the Instructor.
Note: See MAT 405. Students may not take this course for credit if they have received credit for MAT 405.

PHY 380 Experiential Learning in Astronomy 3-3-0
Students will be expected to work in the Observatory as a telescope operator, guide, and/or public speaker. These activities will help fulfill the Observatory's role as a resource for public outreach in the field of science. Students will be expected to become conversant with the essentials of observational astronomy and to develop their ability to articulate the importance of astronomy and science to the general public through oral and/or written communication. Students must seek out an internal supervisor (a full-time faculty member) who will supervise their activities. Assessment of the student will be based on a mark assigned by the supervisor and will reflect the quality of the work carried out by the student. Students must also submit a journal detailing the actual daily work that was accomplished. Projects may be intensive in nature (i.e., 3 weeks during the summer), or may extend over longer durations (i.e., 6-8 hours per week during the semester).
Note: Students may only take one experiential learning course for credit. Permission of the instructor.

PHY 381 Research Based Experiential Learning 3-0-9
Students will be engaged in modern research in the field of physics and astronomy to gain hands-on experience with research to better connect the student to physics theory and knowledge that has already been learned in the classroom.
Prerequisite: Permission of the instructor.
Note: Students may only take one experiential learning course for credit.

PHL 385 Intermediate Physics Lab I 2-0-6
Introduction to data acquisition and analysis of experiments which serve to measure the fundamental constants or properties of nature (e.g., Planck's constant, Boltzmann's constant, speed of light, charge of the electron, Landé g-factor). Data will be collected by using a variety of instruments including oscilloscopes, computer interfaces using A/D converters, and other data sensors.
Offered alternate years.

PHL 386 Intermediate Physics Lab II 2-0-6
Experiments in quantum physics, non-linear dynamics (chaos), thermodynamics, and low-temperature physics will be carried out. Computer interfaces and nuclear counters will be used to collect and analyze data.
Offered alternate years.

PHY 462 Quantum Mechanics II 3-3-0
Theory of angular momentum, matrix mechanics and applications of quantum mechanics to various branches of physics. Perturbation theory, scattering, molecular applications, and Hartree-Fock theory.
Prerequisite: PHY 361.

PHY 463 Nuclear Physics 3-3-0
Nuclear structure and systematics; alpha emission, beta decay, gamma emission, two-body systems and nuclear reactions; neutron physics; sub-nuclear particles.
Prerequisite: PHY 361.

PHY 464 Condensed Matter Physics 3-3-0
Topics to be studied include the one-electron theory of solids, energy bands, lattice vibrations, transport theory, and thermodynamic properties.
Prerequisite: PHY 317, or permission of the department.

PHY 465 Electromagnetic Theory 3-3-0
Static and dynamic electric and magnetic fields; Maxwell's equations and solutions involving plane waves. Covariant formulation of electromagnetic field theory.
Prerequisite: PHY 321.

PHY 466 Theoretical Topics 3-3-0
Topics to be studied will be selected from the areas of special and general relativity, classical and quantum mechanics, particle physics, astrophysics, and cosmology. In particular, the covariant nature of physics and various physical symmetries will be investigated.
Prerequisites: PHY 317, PHY 318; or permission of the instructor.
Note: see PHY 566. Students who take this course for credit may not receive credit for PHY 566.

PHY 467 Advanced Statistical Mechanics 3-3-0
Derivation of the laws of thermodynamics from statistical principles. Quantum statistics, arbitrarily degenerate and relativistic perfect gases, transport theory, thermodynamic fluctuations, and low-temperature physics will also be studied.
Prerequisite: PHY 317.

PHY 469 Independent Studies I 3-0-0
Topics to be determined by the instructor based on student's needs.

PHY 470 Independent Studies II 3-0-0
Topics to be determined by the instructor based on student's needs.

PHY 471 Independent Studies III 3-0-0
Topics to be determined by the instructor based on student's needs.

PHY 474 Cosmology 3-0-0
Topics to be studied include: cosmology, inflation, dark energy, compact objects, *relativistic fluid dynamics, gravitational lensing, and gravitational waves.*
Prerequisite: PHY 208, PHY 214; or permission of the instructor.
Note: See PHY 574. Students who take this course for credit may not receive credit for PHY 574.

PHY 475 Numerical Methods and Simulations 3-3-0
This course will cover selected topics in High Performance Computing including cellular automata, finite element methods, molecular dynamics, Monte Carlo methods, and multigrid methods. Applications of the algorithms to the study of classical fields, fluid dynamics, materials properties, nanostructures, and biomolecules will be addressed depending on the interests of the students.
Note: See PHY 575. Students may not take this course for credit if they have received credit for PHY 575.

PHY 476 Stellar Astrophysics 3-3-0

An introduction to the properties of stellar atmospheres and interiors. The equations of stellar evolution, nuclear energy generation, radiative transport and stellar model building will be studied. Further topics include the formation of stars, and the physics associated with supernovae, white dwarfs, neutron stars, pulsars and black holes.

Prerequisite: PHY 208, PHY 214; or permission of the instructor.

Note: See PHY 576. Students who take this course for credit may not receive credit for PHY 576.

PHY 480 Honours Research Dissertation 6-1-6

Each student is required to carry out either an experimental or theoretical project under the supervision of a faculty member. A plan outlining the proposed research must be submitted for approval during the first four weeks of the course. Each student will present his/her results in the form of a seminar, an oral thesis defense, and a written dissertation.

Prerequisite: U3 Honours Physics registration or permission of the department.

PHY 487 Exoplanet Astrophysics 3-3-0

Exoplanets are planets in orbit around distant stars. This course is designed as an introduction to the discovery and characterization of exoplanets. The application of transits, velocimetry, imaging and lensing will be studied. Exoplanet atmospheres, interiors and orbital dynamics will be studied. Further topics include demographics, biosignatures and exploration of our Solar System to understand the origins of life.

Prerequisites: PHY 208, PHY 214; or permission of the instructor.

Note: See PHY 587. Students who take this course for credit may not receive credit for PHY 587.

PHY 488 Statistics and Machine Learning for Physics 3-3-0

Theory and applications of modern techniques in statistics and machine learning for physics and astronomy. Topics covered include: frequentist statistics and Bayesian inference, dimensionality reduction, density estimation and clustering, regression and model selection, classification, Gaussian processes, and deep learning. Some frontier topics such as simulation-based inference and transformers will be covered.

Note: See PHY 588. Students who take this course for credit may not receive credit for PHY 588.

Prerequisites: PHY 206, PHY 208, CS 211

Co-requisite: PHY 325