Physics

Physics is often regarded as the cornerstone of the Natural Sciences. It encompasses a diverse range of disciplines including electronics, astrophysics, particle physics, and solid state physics. The BSc Honours program prepares students for direct entry into graduate work in physics (leading to an MSc or PhD degree). The BSc Major program prepares students for industry, education and, on completion of a qualifying year, graduate work in physics. The Major program has sufficient electives to allow a substantial number of courses to be taken in another discipline (minor program), or even a second Major program in a related discipline.

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

Undergraduate Programs

Entrance Requirements (BSC)

Quebec Students:

To enter a Physics program, a student from Quebec must normally have a Quebec collegial diploma (D.E.C.) in science, or the equivalent, including Mathematics NYA, NYB, Physics NYA, NYB, Chemistry NYA, NYB, and Biology NYA. While Physics NYA and NYB are accepted as the prerequisite for the Physics programs, Physics NYC is strongly recommended as a satisfactory preparation. Students having these prerequisites can normally complete their undergraduate program in three years.

Non-Quebec Students:

Students entering a four-year degree program (after completion of Ontario OSSD, grade 12 in other provinces, or the US equivalent) must register in the required collegial equivalent science courses (Chemistry, Mathematics and Physics 191, 192, and all related lab courses) in their first year. They must also register in their first year for English Language 116, or another English course, and also three additional credits selected from Humanities courses in English, History, Classical Studies, Philosophy, Religion or Liberal Arts.

Minor:

A minor in Physics consists of Physics 101a, 106, 107, 117a and four other lecture courses in Physics selected from 200 level courses. The total course credit requirement for the minor is 24 credits.

Major:

The following courses are required for a Physics Major: Physics 101a, 106a, 107b, 117a, 210a, 211b, 212b, 213a, 214b, 216b, 218b, 220a, 270a, 271b. Mathematics 106a, 107b, 108a, 109b, Computer Science 111ab.

Total: 42 course credits physics, 12 credits mathematics, 4 credits computer science, 33 credits options, = 91 course credits.

When any lecture course (e.g., Phy 106a) also has an associated laboratory course (e.g. Phy 186a), 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.

Honours:

The following courses are required for the Physics Honours degree: All of the courses required for a Physics Major and Mathematics 217a, Physics 461a, 462b, 480, plus any one of Physics 463, 464, 465, 466, 467, 469, 470, and 476.

Total Requirements: 57 course credits Physics, 15 credits Mathematics, 4 credits Computer Science, and 15 credits of elective courses = 91 course credits.

When any lecture course (e.g., Phy 106a) also has an associated laboratory course (e.g. Phy 186a), 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.

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 U1 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.

Laboratory Courses:

When any lecture course (e.g., Phy 106a) also has an associated laboratory course (e.g. Phy 186a), 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.

Graduate Programs

Entrance Requirements (MSc):

Students who have completed a BSc degree in physics with at least a B average will be considered for admission into the graduate program. Students who have completed only a major in the subject may be required to take additional courses at the Master's level. Students who have been admitted will be assigned a supervisor by the Chair of Physics. The student's research interests will be taken into consideration when a supervisor is assigned. Current areas of research in the department include astrophysics, condensed matter physics, gravity and cosmology, particle physics and theoretical physics.

Course Requirements (MSc):

The MSc degree requires the successful defense of a thesis (15 credits), participation in the seminar series (18 credits), and the completion of a minimum of 12 credits in course work. Course selection is determined in consultation with the thesis supervisor and departmental chair. All MSc students must make an oral presentation and defense of their thesis before graduating. The normal period for completion of the M.Sc. degree requirements is two academic years (four semesters). The minimum number of credits required to complete the program is 45.

COURSE GROUPINGS

Elective Courses

These courses are open to any students with little or no scientific background (some restrictions apply).

PHY111 Physics of Everyday Phenomena
PHY112 Introduction to Holography
PHY113 Introduction to Astronomy
PHY114 Astronomy and Astrophysics

Physics Major Courses

Four-year Program (BSc)

1st year: Courses have numbers that start with 191 to 199.
2nd year: Courses have numbers that start with 100 to 190.
3rd year: Courses have numbers that start with 200 and end at 399.
4th year: Courses have numbers that start with 200 and end at 399.

Three-year Program (BSc)

1st year: Courses have numbers that start with 100 to 190.
2nd year: Courses have numbers that start with 200 and end at 399.
3rd year: Courses have numbers that start with 200 and end at 399.

Physics Honours Courses

Final-year Honours physics courses have numbers that start with 400 and end at 480.

Graduate Courses

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

Physics 191a 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.

Corequisite: Mathematics 191a, or 198a

This course should be taken concurrently with Physics 081. 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 Physics 191a, 193a or 199f.

Physics 081a Introductory Physics Laboratory I 1-0-4

A series of experiments in General Physics to complement the material covered in Physics 191a.

This course must be taken concurrently with Physics 191a. May not be taken for credit if credit has been granted for Physics 083a.

Physics 192b 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: Physics 191a, 193a, or the permission of the instructor.

Corequisite: Mathematics 192b, or 199b

This course should be taken concurrently with Physics 082. 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 Physics 192b, 194b or 199f.

Physics 082b Introductory Physics Laboratory II 1-0-4

A series of experiments in General Physics to complement the material covered in Physics 192b.

This course must be taken concurrently with Physics 192b. May not be taken for credit if credit has been granted for Physics 084b.

Physics 193a 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.

Corequisite: Mathematics 191a or Mathematics 198a

This course should be taken concurrently with Physics 083. 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 Physics 191a, 193a, and 199f.

Physics 083a Physics for the Life Sciences Laboratory I 1-0-4

A series of experiments in college physics to complement the material covered in Physics 193a.

This course must be taken concurrently with Physics 193a. May not be taken for credit if credit has been granted for Physics 081a.

Physics 194b 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: Physics 191a or Physics 193a or the permission of the instructor.

Corequisite: Mathematics 192b or Mathematics 199b.

This course should be taken concurrently with Physics 084. 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 Physics 192b, 194b, and 199f.

Physics 084b Physics for the Life Sciences Laboratory II 1-0-4

A series of experiments in college physics to complement the material covered in Physics 194b.

This course must be taken concurrently with Physics 194b. May not be taken for credit if credit has been granted for Physics 082b.

Physics 199 Introduction to University Physics 6-6-0

An introduction to the fundamentals of classical physics. Concepts and problem-solving skills are emphasized. Topics in the area of mechanics include: translational, rotational, and oscillatory motion; Newtonian dynamics; conservation of energy, linear momentum, and angular momentum; heat and the kinetic theory of gases. Topics in the area of electricity and magnetism include: electric fields and potentials; AC and DC circuit theory; magnetism and the properties of magnetic materials; electromagnetic waves and optics.

Prerequisites: Students must normally have completed upper-level high school physics and mathematics courses, or must satisfy admission requirements into the B.Sc. degree at Bishop's University. Students taking this course require a knowledge of basic calculus which may be gained concurrently.

Corequisite: Physics 089

Students may not have credit for both Physics 199 and other introductory physics courses (i.e., Physics 191 and 192 or their equivalents).

Physics 089 Introduction to University Physics Laboratory 2-0-8
A series of experiments that complements the lecture material in PHY199. This laboratory course includes experiments in measurement and uncertainty, statics, dynamics, collisions, AC and DC circuit analysis, electrostatics, magnetism optics and thermodynamics.
Corequisite: Physics 199
Students may not have credit for both Physics 089 and other introductory physics laboratory courses (i.e., Physics 081 and 082 or their equivalents).

Physics 101a Statistical Methods in Experimental Science 3-3-1
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.
Note: In order for students to obtain credit for both Physics 101 and Mathematics 213, Physics 101 must be taken first or concurrently. Students who are enrolled in, or who have credit for, PMA160, BMA141, or EMA141 may not enrol in this course.

Physics 106 Waves and Optics 3-3-0
Wave phenomena. Wave and photon theories of light. Huygen's Principle and its applications. Geometrical optics. Optical instruments. Basic models of Interference, Diffraction and Polarization of light.
Co-requisite: Physics 186a

Physics 086 Waves, Optics, & Electromagnetism Laboratory 1-0-4
A series of experiments in wave motion, geometrical and physical optics, and electricity and magnetism to complement the material covered in the lecture courses Physics 192b and Physics 106b. This course must be taken concurrently with Physics 192b and Physics 106b.
Co-requisites: Physics 192b and Physics 106b

Physics 186 Waves and Optics Laboratory 1-0-4
Experiments in geometrical and physical optics. This course must be taken concurrently with Physics 106a.

Physics 107 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.
NOTE: See Environmental Science 167. Students may not take this course for credit if they have received credit for Environmental Science 167.

Physics 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 Division of Natural Sciences and Mathematics cannot use this course for science credits.

Physics 112/Fine Arts 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.
See Fine Arts 209
Students may not take this course for credit if they have received credit for Fine Arts 209
Students enrolled in a program in the Division of Natural Sciences and Mathematics cannot use this course for science credits.

Physics 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.

Physics 114 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: Mathematics 191 (or equivalent), or permission of the instructor.

Physics 117a 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 motion of particles; rotation of macroscopic bodies. Non-Inertial Frames.
Prerequisite: Physics 191a or equivalent
Corequisite: Mathematics 106a
Note: See MAT177a. Students may not take this course for credit if they have received credit for MAT177a.

Physics 210a Electricity and Magnetism 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.
Prerequisite: Physics 117a, Mathematics 107b; corequisite Physics 284
Offered alternate years

Physics 211b Electricity and Magnetism 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: Physics 210a
Offered alternate years

Physics 212 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.
Note: See CSC 272.
Students may not take this course for credit if they have received credit for Computer Science 272.
Prerequisite: Permission of instructor.

Physics 213a Modern Physics I 3-3-0
Fundamentals of modern physics, special theory of relativity, quantization of electromagnetic radiation, wave properties of particles, the hydrogen atom, atomic and X-ray spectra.
Prerequisite: Physics 106a, or permission of the instructor; co-requisite Physics 283
Offered alternate years

Physics 214b Modern Physics II 3-3-0
Schrodinger's Equation. The hydrogen atom, orbital theory, and the Zeeman effect. Overview of solid state physics. Nuclear structure, nuclear decay, nuclear models, nuclear reactions, and nuclear detectors. Elementary particles.
Prerequisite: Physics 213a
Offered alternate years

Physics 216 Physical and Contemporary Optics 3-3-0
Wave theory, polarization, interference diffraction. Basics of coherence theory, lasers, holography. Quantum nature of light.
Prerequisite: Physics 106a
Offered alternate years

Physics 218 Advanced Mechanics 3-3-0
Newtonian gravitation: planetary orbits; tides. The Lagrangian and Hamilton's Principle. Applications to the dynamics of particles. Theory of Vibrations and Small Oscillations. Dynamics of macroscopic bodies. Non-linear dynamics.
Prerequisite: Physics 117a, Physics 270a, or permission of the instructor.
Offered alternate years
Note: See Mat 278. Students may not take this course for credit if they have received credit for Mat 278.

Physics 220 Statistical and Thermal Physics 3-3-0
The statistical definition of entropy and temperature. Statistical Ensembles. The Planck and Maxwell-Boltzmann distributions. The Fermi and Bose distributions. Thermodynamic functions. Applications of Fermi-Dirac and Bose-Einstein statistics.
Prerequisite: Physics 107b
Offered alternate years

Physics 230b Relativity Theory 3-3-0
The geometry of space-time. Covariance. Relativistic mechanics of particles in curved space-times. Electromagnetic radiation. Einstein's field equations. Applications to cosmology.
Prerequisite: Physics 117a

Physics 265b Data Communications 3-3-0

This course will cover how data flows in communications networks. Topics: Hardware, software and basic components of data communications; frequency domain representation, modulation, multiplexing; network configurations.
Prerequisite: Computer Science 111ab, Computer Science 116a, or permission of the instructor.
Note: See Computer Science 215b. Students may not take this course for credit if they have received credit for Computer Science 265b.

Physics 270a Differential Equations 3-3-0
Techniques for solving first and second order linear differential equations. Systems of first order equations. Power series solutions for second order equations including the method of Frobenius. Various applications of differential equations.
Prerequisite: Mathematics 107b
Note: See Mathematics 210a. Students may not take this course for credit if they have received credit for Mathematics 210a.

Physics 271b Mathematical Methods of Physics 3-3-0
Discussion of series solutions in connection with the gamma function and Bessel, Legendre and hypergeometric functions. Laplace transform with applications. Elementary trigonometric Fourier series and boundary value problems. Certain partial differential equations of physics.
Prerequisites: Mathematics 210a or Physics 270a
Note: See Mathematics 211a. Students may not take this course for credit if they have received credit for Mathematics 211b.

Physics 274ab 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.
Prerequisites: PHY 101 (or equivalent)
See CSC 205
Students may not take this course for credit if they have received credit for Computer Science 205.

Physics 275 Numerical Methods 3-3-0
A course introducing those numerical methods best suited to a computer. Error analysis, roots of equations, QR-algorithm, interpolation, Numerical approaches to differentiation, integration and solutions of differential equations.
Prerequisites: Computer Science 111ab. Mathematics 107, 108
Note: See Mathematics 225 and CSC 275. Students may not take this course for credit if they have received credit for Mathematics 225 or Computer Science 275.

Physics 276 Calculus of Variations 3-3-0
Euler-Lagrange equations for constrained and unconstrained single and double 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 MAT305. Students may not take this course for credit if they have received credit for MAT305.

Physics 278 Scientific Programming 3-3-3
This course is designed as an introduction to programming languages and environments suitable for the numerically intensive applications in the natural sciences and mathematics. Examples will be given to illustrate the use of Fortran in numerical calculations. Other examples will be tackled using the Maple language initially developed to handle problems in symbolic computation.
Prerequisite: CSC 204
Note: See CSC 208 and MAT 279. Students may not take this course for credit if they have received credit for CSC208 or MAT 279.

Physics 283f Intermediate Physics Laboratory I 2-0-4
Experiments in modern physics, classical mechanics, thermodynamics, and low-temperature physics will be carried out. Computer interfaces will be used to collect and analyse data.
Corequisite: Physics 213a
Offered alternate years

Physics 284f Intermediate Physics Laboratory II 2-0-4
Experiments in electricity and magnetism, electronics, and physical optics will be carried out. Computer interfaces will be used to collect and analyse data.
Corequisite: Physics 210a
Offered alternate years

Physics 335/ENV 375 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.

Prerequisites: Environmental Science 101; Physics 107 ***or*** *Environmental Science 167.*
Note : See Environmental Science 375. Students may not take this course for credit if they have received credit for Environmental Science 375.

Physics 461a Quantum Mechanics I 3-3-0
Foundation of quantum mechanics; Schrodinger equation, angular momentum, central potentials, harmonic oscillator, hydrogen atom.
Prerequisite: Physics 214b or permission of the instructor.

Physics 462b Quantum Mechanics II 3-3-0
Matrix mechanics and applications of quantum mechanics to various branches of physics. Perturbation theory, scattering, molecular applications, and Hartree-Fock Theory.
Prerequisite: Physics 461a

Physics 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: Physics 461a

Physics 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: Physics 214, 220, or permission of the department.

Physics 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: Physics 211b

Physics 466ab Theoretical Topics 3-3-0
Topics to be studied will be selected from the areas of special and general relativity, particle physics, astrophysics and cosmology. In particular, the covariant nature of physics and various physical symmetries will be investigated.
Prerequisites: Physics 214, 218, 220; or the permission of the instructor

Physics 467 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: Physics 220b

Physics 469a Independent Studies I 3-0-0

Physics 470b Independent Studies II 3-0-0

Physics 474ab Relativistic Astrophysics 3-0-0
Topics to be studied include: Cosmology, inflation, dark energy, compact objects, relativistic fluid dynamics, gravitational lensing and gravitational waves.
See Physics 574
Students who take this course for credit may not receive credit for Physics 574.

Physics 475 Numerical Methods & 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.
See Physics 575ab. Students may not take this course for credit if they have received credit for Physics 575ab.

Physics 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.

Physics 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 and a written dissertation.
Prerequisite: U3 Honours Physics registration or permission of the department.

Physics 561 Quantum Mechanics I 3-3-0
Foundation of quantum mechanics; Schrodinger equation, angular momentum, central potentials, harmonic oscillator, hydrogen atom.
Prerequisite: Physics 214b or permission of the instructor.
Students who have received credit for Physics 461a may not enrol in this course.

Physics 562 Quantum Mechanics II 3-3-0

Matrix mechanics and applications of quantum mechanics to various branches of physics. Perturbation theory, scattering, molecular applications, and Hartree-Fock Theory.
Prerequisite: Physics 461a
Students who have received credit for Physics 462b may not enrol in this course.

Physics 564 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: Physics 214, 220, or permission of the department.
Students who have received credit for Physics 464 may not enrol in this course.

Physics 565 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: Physics 211b
Students who have received credit for Physics 475 may not enrol in this course.

Physics 566 Theoretical Topics 3-3-0
Topics to be studied will be selected from the areas of special and general relativity, particle physics, astrophysics and cosmology. In particular, the covariant nature of physics and various physical symmetries will be investigated.
Prerequisites: Physics 214, 218, 220; or the permission of the instructor.

Physics 567 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: Physics 220b
Students who have received credit for Physics 467 may not enrol in this course.

Physics 571 Advanced Quantum Theory 3-3-0
Topics to be studied include: Path integral and second quantization approaches to non-relativistic quantum mechanics. Feynman rules and diagrams. Relativistic quantum field of spin-zero particles.

Physics 572 Particle Physics 3-3-0
Quantum field theory of spin 1⁄2 and spin 1 particles will be introduced. Topics include: renormalization and the renormalization group; quantum electrodynamics and quantum chromodynamics; the Standard Model of particle physics; overview of string theory.

Physics 573 Advanced General Relativity 3-3-0
Topics to be studied include: differential geometry, Einstein equations, the weak field limit, gravitational waves, black holes, and relativistic cosmology.

Physics 574 Relativistic Astrophysics 3-3-0
Topics to be studied include: Cosmology, inflation, dark energy, compact objects, relativistic fluid dynamics, gravitational lensing, and gravitational waves.

Physics 575 Numerical Methods & 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, with applications to classical fields, fluid dynamics, materials properties, nanostructures, and biomolecules.

Physics 576 Stellar Astrophysics I 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 starts, and the physics associated with supernovae, white dwarfs, neutron stars, and pulsars.

Physics 577 Many-Body Quantum Theory in
Condensed Matter Systems 3-3-0
The following topics will be studied: Green's functions at zero and finite temperature; the interacting electron gas; the Hubbard model and strongly correlated systems; electron-phonon interaction; superconductivity and superfluidity.

Physics 578 Selected Topics in Astronomy & Astrophysics 3-3-0
Topics to be determined in consultation with prospective students.

Physics 579 Selected Theoretical Topics 3-3-0
Topics to be determined in consultation with prospective students.

Physics 580f Graduate Seminar I 9-0-0
Students are expected to participate in the departmental seminar series and to make a presentation on either their own work or on a research-related topic. All M.Sc. Students are normally expected to enrol in this course at the beginning of their first year of studies.
Offered alternate years with Physics 581.

Physics 581f Graduate Seminar II 9-0-0
Students in the second year of their degree program are expected to participate in the departmental seminar series and to make a presentation on either their own work or on a research-related topic.

Course offered alternate years with Physics 580.

Physics 586 Stellar Astrophysics II 3-3-0

A detailed study of the physics that determines the evolution of stars during all of their possible phases. This includes radiative hydrodynamics and atmospheric modeling, specialized equations of state, and the nuclear physics needed to understand the various channels that lead to the creation of the heavy elements. The physics of neutrino production and detection will also be investigated. These topics will form the basis for a study of the evolution of supernovae and other high-energy phenomena in stellar astrophysics.

Physics 600ab Thesis Research Dissertation 15-0-0

Each student is required to carry out independent, publishable research that is presented in the form of a thesis. The research is conducted under the supervision of a faculty member. The thesis will be evaluated externally and must be successfully defended in a meeting that is open to all members of the department.