

PHYSICS, ENGINEERING PHYSICS AND ASTRONOMY

Departmental Notes

Subject Code for Astronomy: **ASTR**

Subject Code for Physics: **PHYS**

World Wide Web Address: www.queensu.ca/physics/home
(<http://www.queensu.ca/physics/home/>)

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Department Manager: Julie McDonald (jmm27@queensu.ca)

Overview

Through studying Physics at Queen's, you will be trained in observation and experimentation, in applied mathematics and model building, and will develop the confidence to tackle new and intellectually demanding problems. This will place you at the leading edge of research and development in science and technology. This program deals with the properties of matter and energy, from everyday concepts such as force, heat and electricity, to the abstract ideas of relativity and quantum mechanics. The Department of Physics, Engineering Physics and Astronomy also offers a Specialization Plan in Astrophysics (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/astrophysics-specialization-science-bs-honours/>), and jointly with the Department of Mathematics and Statistics, a Specialization Plan in Mathematical Physics (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/mathematical-physics-specialization-science-bs-honours/>).

Advice to Students

Astronomy and Astrophysics

Astronomy courses at Queen's are offered by the Department of Physics, Engineering Physics and Astronomy, which has a research group active in astronomy and astrophysics. Students intending to specialize in astronomy or astrophysics at the graduate level should consider the Astrophysics Specialization Plan (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/astrophysics-specialization-science-bs-honours/>).

[public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/astrophysics-specialization-science-bs-honours/](https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/astrophysics-specialization-science-bs-honours/)). Students wishing to include a course in astronomy as an elective should refer to ASTR 101, ASTR 102 and PHYS 216.

First Courses in Physics

PHYS 104 and PHYS 106 are intended for students in the physical and mathematical sciences. Both are calculus-based courses. A grade of at least B- in either of these courses is recommended for entry into PHYS 206, PHYS 239, and PHYS 242, which are required courses for most Physics Plans.

PHYS 115 and PHYS 116 are designed for students in the biological and life sciences. 4U physics is recommended but not required; neither is a previous or concurrent calculus course, although some 4U or equivalent mathematics is required. PHYS 118 has similar content to PHYS 115 and PHYS 116, but has no lab component and is offered online only.

ASTR 101, ASTR 102, PHYS P22, PHYS 260, and PHYS 216 are attractive electives for students in other disciplines. PHYS P22, ASTR 101, and ASTR 102 can count toward a Minor(Arts) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-minor-arts/>) or General(Arts) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-general-arts-ba/>) in Physics, but are only electives in other Physics Plans.

Students with an A standing in both PHYS 115 and PHYS 116 and, C in MATH 120 or MATH 121 may be admitted to a Physics Plan (with PHYS 115 and PHYS 116 then satisfying the first-year physics core requirement), but only after consultation with, and approval from, the Department.

Ancillary Fees

Please note that in some courses you may be asked to purchase a lab or course manual containing material(s) specific to the lab/course content. Prices generally range from \$15 to \$25 per manual and are sold through Physics Stores.

Faculty

For more information, please visit: <https://www.queensu.ca/physics/people/people-directory> (<https://www.queensu.ca/physics/people/people-directory/>)



- Joe Bramante
- Alexander Braun
- Tucker Carrington Jr.
- Mark C. Chen
- Lynann Clapham
- Ken Clark
- Stéphane Courteau
- Philippe Di Stefano
- Marc Dignam
- Laura Fissel
- James Fraser
- Jun Gao
- Gilles Gerbier
- Guillaume Giroux
- R.J. Gooding
- Stephen Hughes
- Judith Irwin
- Robert Knobel
- Thomas Krause
- Kayll W. Lake
- H.P. Loock
- Ryan Martin
- Alastair B. McLean
- Jordan Morelli
- K.S. Narayanan
- A.J. Noble
- Jean Michel Nunzi
- Nahee Park
- Nir Rotenberg
- Sarah Sadavoy
- Bhavin J. Shastri
- Kristine Spekkens
- James Stotz
- Anne Topper
- Greg van Anders
- Aaron Vincent
- Gregg Wade
- Lawrence M. Widrow
- Alex Wright

Specializations

- Astrophysics – Specialization (Science) – Bachelor of Science (Honours) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/astrophysics-specialization-science-bs-honours/>)

- Mathematical Physics – Specialization (Science) – Bachelor of Science (Honours) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/mathematical-physics-specialization-science-bs-honours/>)
- Physics – Specialization (Science) – Bachelor of Science (Honours) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-specialization-science-bs-honours/>)

Major

- Physics – Major (Science) – Bachelor of Science (Honours) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-major-science-bs-honours/>)

Generals/Minors

- Physics – General (Arts) – Bachelor of Arts (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-general-arts-ba/>)
- Physics – General (Science) – Bachelor of Science (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-general-science-bs/>)
- Physics – Minor (Arts) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-minor-arts/>)
- Physics – Minor (Science) (<https://queensu-ca-public.courseleaf.com/arts-science/schools-departments-programs/physics-engineering-astronomy/physics-minor-science/>)

Courses

Astronomy (ASTR)

ASTR 101 Astronomy I: Solar System Units: 3.00

A non-mathematical introduction to the science of astronomy for non-specialist students. Topics to be covered include the fundamentals of astronomy; and introduction to the tools and techniques of modern observational astronomy; the historical development of our understanding of the Earth, Moon, and Solar System; space exploration of Mars, Jupiter, and other planets; the nature of the Sun; and the origin and uniqueness of our Solar System.

NOTE Also offered online, consult Arts and Science Online (Learning Hours may vary).

NOTE Also offered at Bader College, UK (Learning Hours may vary).

Learning Hours: 120 (36 Lecture, 24 Online Activity, 60 Private Study)

Requirements: Prerequisite None.

Offering Faculty: Faculty of Arts and Science

ASTR 102 Astronomy II: Stars, Galaxies, and the Universe Units: 3.00

This course, intended for non-specialist students, will provide an overview of astronomy beyond the Solar System. Topics will include: the formation, nature, and evolution of the stars; stellar deaths, including novae, supernovae, white dwarfs, neutron stars, pulsars, and black holes; the interstellar medium; the Milky Way Galaxy; normal and active galaxies and large scale structure in the universe; and modern ideas in cosmology and the early universe.

NOTE Also offered online, consult Arts and Science Online (Learning Hours may vary).

Learning Hours: 120 (36 Lecture, 24 Online Activity, 60 Private Study)

Requirements: Prerequisite (ASTR 101/3.0 or PHYS 104/6.0 or PHYS 106/6.0 or PHYS 117/6.0 or PHYS 118/6.0 or [APSC 111/3.3 and APSC 112/3.3]) or permission of the Department.

Offering Faculty: Faculty of Arts and Science

Physics (PHYS)

PHYS P10 Fundamental Concepts in Physics for Teachers Units: 3.00

A course relevant to those interested in teaching. Activity-based learning of fundamental physics topics typically taught in elementary and secondary schools. Topics include: motion, forces, energy, heat, electricity and magnetism, and light. Students will be required to teach a one-hour enrichment class, once a week for 10 weeks, to Grade 7 or 8 students in a local school.

NOTE This course may not be included in any Plan in Physics other than a Minor.

Offering Faculty: Faculty of Arts and Science

PHYS P22 Physics Frontiers: From Colliding Black Holes to Disruptive Technologies Units: 3.00

A descriptive course exploring concepts in physics at the frontiers of active research. Bypassing jargon and mathematical complexities, students will focus on the big questions at the extremes of our understanding of the universe around us. Designed for non-scientists who want to learn how we try to understand our fantastic, physical natural world.

Learning Hours: 114 (24 Lecture, 24 Practicum, 36 Online Activity, 18 Off-Campus Activity, 12 Private Study)

Offering Faculty: Faculty of Arts and Science

PHYS 104 Fundamental Physics Units: 6.00

Mechanics, including systems of particles and rigid body motion; gravitation; fluids; electricity and magnetism; oscillatory motion and waves; topics in modern physics. The material is presented at a more fundamental level appropriate for students who are seeking a deeper appreciation of physics, and who may be considering a concentration in Physics.

Learning Hours: 240 (72 Lecture, 36 Laboratory, 36 Tutorial, 96 Private Study)

Requirements: Prerequisite None. Corequisite (MATH 120 or MATH 121 or [MATH 123 and MATH 124]). Exclusion PHYS 106; PHYS 115; PHYS 116; PHYS 117/6.0; PHYS 118; PHYS 119. Recommended 4U Physics.

Offering Faculty: Faculty of Arts and Science

PHYS 106 General Physics Units: 6.00

Mechanics, including systems of particles and rigid body motion; fluids; electricity and magnetism; oscillatory motion and waves; heat, light and sound; topics in modern physics. Aspects of physics useful for further work in other sciences will be emphasized.

NOTE Also offered at the Bader College, UK. Learning Hours may vary.

Learning Hours: 240 (72 Lecture, 36 Laboratory, 36 Tutorial, 96 Private Study)

Requirements: Prerequisite None. Corequisite (MATH 120 or MATH 121 or [MATH 123 and MATH 124]). Exclusion PHYS 104; PHYS 115; PHYS 116; PHYS 117/6.0; PHYS 118; PHYS 119. Recommended 4U Physics.

Offering Faculty: Faculty of Arts and Science

**PHYS 115 Introduction to Physics I Units: 3.00**

An algebra-based course dealing with basic physics concepts, including dynamics, fluids, and basic thermodynamics.

PHYS 115 includes a required lab component.

NOTE PHYS 115 and PHYS 116 together, are equivalent to PHYS 117/6.0.

NOTE Manual: estimated cost \$5.

Learning Hours: 132 (36 Lecture, 12 Laboratory, 12 Tutorial, 72 Private Study)

Requirements: Prerequisite None. Exclusion PHYS 104; PHYS 106; PHYS 117/6.0; PHYS 118; PHYS 119.

Offering Faculty: Faculty of Arts and Science

PHYS 116 Introduction to Physics II Units: 3.00

An algebra-based course dealing with basic physics concepts, including waves, electromagnetism, and basic optics.

PHYS 116 includes a required lab component.

NOTE PHYS 115 and PHYS 116 together, are equivalent to PHYS 117/6.0.

NOTE Manual: estimated cost \$5.

Learning Hours: 132 (36 Lecture, 12 Laboratory, 12 Tutorial, 72 Private Study)

Requirements: Prerequisite PHYS 115. Exclusion PHYS 104; PHYS 106; PHYS 117/6.0; PHYS 118; PHYS 119.

Offering Faculty: Faculty of Arts and Science

PHYS 118 Basic Physics Units: 6.00

An algebra-based course dealing with basic Physics concepts, including dynamics, fluids, waves, electromagnetism, and basic optics. Emphasis is placed on the development of problem-solving skills through the use of Mastery based course delivery.

NOTE Only offered online. Consult Arts and Science Online.

Learning Hours: 228 (132 Online Activity, 96 Private Study)

Requirements: Prerequisite None. Recommended 4U Physics.

Exclusion PHYS 104/6.0; PHYS 106/6.0; PHYS 115/3.0; PHYS 116/3.0; PHYS 117/6.0.

Course Equivalencies: PHYS 118/118B

Offering Faculty: Faculty of Arts and Science

PHYS 119 Introductory Physics Laboratory Units: 1.50

This is the laboratory portion of PHYS 117, offered for students who completed the online PHYS 118 Basic Physics course, but would like a laboratory experience. A laboratory class in mechanics, electricity, waves and optics. This course runs 8 experiments through the fall and winter terms.

Requirements: Prerequisite PHYS 118/6.0.

Exclusion PHYS 104/6.0; PHYS 106/6.0; PHYS 115/3.0; PHYS 116/3.0; PHYS 117/6.0.

Offering Faculty: Faculty of Arts and Science

PHYS 206 Dynamics Units: 3.00

An introductory course in classical dynamics of particles, of rigid bodies and of fluids that sets the foundation for more advanced work. Topics include kinematics of particles and of rigid bodies, central forces, kinetics of systems of particles, planar and three dimensional dynamics of rigid bodies and an introduction to fluid mechanics.

Requirements: Prerequisite ([PHYS 104 or PHYS 106] and [MATH 120 or MATH 121]) or permission of the Department. Recommended A minimum grade of a C in PHYS 104 or PHYS 106.

Offering Faculty: Faculty of Arts and Science

PHYS 212 Vibrations and Waves Units: 3.00

Fundamentals of free, damped and forced vibrations with applications to various mechanical systems. Coupled oscillations and normal modes. Classical wave equation, standing and travelling waves. Continuum mechanics of solid bodies; elasticity theory with applications. Introduction to optics: image formation and optical instruments.

Learning Hours: 120 (24 Lecture, 24 Tutorial, 72 Private Study)

Requirements: Prerequisite PHYS 206.

Offering Faculty: Faculty of Arts and Science

PHYS 213 Computational Methods in Physics Units: 3.00

Computing environments, algorithms, techniques and programming for solving physics problems. Numerical methods. Code development. Possible topics to be covered include numerical differentiation and integration, root finding and optimization problems, solution of linear systems of equations, Monte Carlo simulation, and symbolic computation.

Learning Hours: 120 (24 Lecture, 24 Tutorial, 72 Private Study)

Requirements: Prerequisite (PHYS 104 or PHYS 106) and (MATH 120 or MATH 121). Exclusion MATH 272; PHYS 313.

Offering Faculty: Faculty of Arts and Science

PHYS 216 Introduction to Astrophysics Units: 3.00

Broad overview of basic laws of gravitation, radiation, and relativity; history and evolution of modern astronomy; ground and space-based astronomy; the physics and evolution of stars; the milky way; galaxies in the universe; and cosmology. This course also uses the on-campus observatory at an introductory level.

Requirements: Prerequisite ([PHYS 104 or PHYS 106] and [MATH 120 or MATH 121]) or permission of the Department.

Offering Faculty: Faculty of Arts and Science

PHYS 239 Electromagnetism Units: 3.00

The experimental basis and mathematical description of electrostatics, magnetostatics and electromagnetic induction, together with a discussion of the properties of dielectrics and ferromagnetics, are presented. Both the integral and vector forms of Maxwell's equations are deduced.

Requirements: Prerequisite (PHYS 104 or PHYS 106) and (MATH 221 or MATH 227 or MATH 280). Recommended A minimum grade of a C in PHYS 104 or PHYS 106.

Offering Faculty: Faculty of Arts and Science

PHYS 242 Relativity and Quanta Units: 3.00

Evidence for relativistic effects. Kinematics and dynamics in special relativity, space-time diagrams, applications. Evidence for quanta, spectra, Bohr atom. Introduction to the Schrodinger equation.

Requirements: Prerequisite PHYS 104 or PHYS 106. Recommended A minimum grade of a C in PHYS 104 or PHYS 106.

Offering Faculty: Faculty of Arts and Science

PHYS 250 Foundations of Experimental Physics Units: 3.00

Laboratory and lecture course that presents techniques and skills that are the foundations of experimental physics. Topics include statistical analysis of data, uncertainties in measurement, propagation of errors, software for data analysis, graphing and reporting. Students will be exposed to techniques in the measurement of electric, magnetic, thermal and mechanical properties. Laboratories also illustrate some principles of quantum physics, mechanics, electromagnetism and thermodynamics learned in other physics courses. Some exposure to computerized data acquisition is included.

Learning Hours: 132 (24 Lecture, 36 Laboratory, 72 Private Study)

Requirements: Prerequisite PHYS 104 or PHYS 106.

Offering Faculty: Faculty of Arts and Science

PHYS 260 The Physics of Light and Colour Units: 3.00

Students will develop an appreciation for the physical and chemical processes that control light and colours. Students will learn the basic principles of light emission and propagation, image formation, the workings of optical devices and detectors, colour theory and colour perception, colour in art, colour in nature, and colours in astronomy.

Learning Hours: 108 (36 Lecture, 72 Private Study)

Requirements: Prerequisite PHYS 104 or PHYS 106 or PHYS 117 or PHYS 118 or BIOL 102 or BIOL 103 or CHEM 112 or GEOL 102 or GEOL 104 or GEOL 106 or GEOL 107 or PSYC 100.

Offering Faculty: Faculty of Arts and Science

PHYS 315 Physical Processes in Astrophysics Units: 3.00

This course relates observable quantities to the physical properties of astronomical sources thereby deciphering the varied nature of the cosmos. Basic physical processes in astrophysics are discussed and applied to diverse systems including planets, stars, the interstellar medium and distant galaxies. Topics include radiative transfer and the perturbation of the signal by instruments, the atmosphere, and the interstellar medium. The main astrophysical emission processes, both continuum and line, are also presented. An observing project will be carried out during the term.

Learning Hours: 120 (36 Lecture, 84 Private Study)

Requirements: Prerequisite (PHYS 216 and PHYS 242) or permission of the Department.

Offering Faculty: Faculty of Arts and Science

PHYS 316 Methods in Mathematical Physics I Units: 3.00

Methods of mathematics important for physicists. Complex arithmetic, series expansions and approximations of functions, Fourier series and transforms, vector spaces and eigenvalue problems, ordinary differential equations and Green's functions.

Learning Hours: 120 (36 Lecture, 12 Tutorial, 72 Private Study)

Requirements: Prerequisite (MATH 221 or MATH 227 or MATH 280) and (MATH 225 or MATH 231 or MATH 232). Exclusion MATH 334; MATH 338; PHYS 312.

Offering Faculty: Faculty of Arts and Science

PHYS 317 Methods in Mathematical Physics II Units: 3.00

A continuation of PHYS 316. Partial differential equations, functions of a complex variable and contour integration, and special topics such as probability and statistics, group theory and non-linear dynamics.

Learning Hours: 120 (36 Lecture, 12 Tutorial, 72 Private Study)

Requirements: Prerequisite PHYS 316. Exclusion MATH 228; MATH 326; MATH 338; PHYS 312.

Offering Faculty: Faculty of Arts and Science

PHYS 321 Advanced Mechanics Units: 3.00

An introduction to the equations of mechanics using the Lagrange formalism and to the calculus of variations leading to Hamilton's principle. The concepts developed in this course are applied to problems ranging from purely theoretical constructs to practical applications. Links to quantum mechanics and extensions to continuous systems are developed.

Requirements: Prerequisite PHYS 212 and (MATH 221 or MATH 227 or MATH 280) and (MATH 225 or MATH 231 or MATH 232).

Offering Faculty: Faculty of Arts and Science

**PHYS 334 Electronics for Physicists Units: 3.00**

The design of electronic circuits and systems, using commonly available devices and integrated circuits. The properties of linear circuits are discussed with particular reference to the applications of feedback; operational amplifiers are introduced as fundamental building blocks. Digital circuits are examined and the properties of the commonly available I.C. types are studied; their use in measurement, control and signal analysis is outlined. Laboratory work is closely linked with lectures and provides practical experience in the subjects covered in lectures.

Requirements: Prerequisite PHYS 239.

Course Equivalencies: PHYS333, PHYS334

Offering Faculty: Faculty of Arts and Science

PHYS 344 Introduction to Quantum Mechanics Units: 3.00

Matter waves. Postulates of wave mechanics. Stationary states and one-dimensional potentials. Particle tunneling and scattering states. Introduction to matrix mechanics and Dirac notation. Quantized angular momentum, and the H atom. NOTE Manual: estimated cost \$20.

Requirements: Prerequisite PHYS 212 and PHYS 242 and (MATH 221 or MATH 280) and (MATH 225 or MATH 231 or MATH 232). Equivalency PHYS 343.

Course Equivalencies: PHYS343, PHYS344

Offering Faculty: Faculty of Arts and Science

PHYS 345 Quantum Physics of Atoms, Nuclei and Particles Units: 3.00

Spin. Addition of angular momentum. Many electron atoms and the periodic table. Introduction to perturbation theory and Fermi's golden rule. Time dependent perturbations, including stimulated emission. Introduction to nuclear and particle physics.

NOTE Manual: estimated cost \$20.

Requirements: Prerequisite PHYS 344. Equivalency PHYS 424.

Course Equivalencies: PHYS345, PHYS424

Offering Faculty: Faculty of Arts and Science

PHYS 350 General Laboratory Units: 6.00

Experiments in heat, optics, electron physics, quantum physics, and radioactivity are performed. A substantial part of the course is an experimental project during the Winter Term. A topic for the experimental physics, or observational astronomy project will be assigned after discussion with the student.

Learning Hours: 222 (72 Laboratory, 6 Online Activity, 144 Private Study)

Requirements: Prerequisite PHYS 239 and PHYS 242 and PHYS 250.

Offering Faculty: Faculty of Arts and Science

PHYS 372 Thermodynamics Units: 3.00

Temperature, equations of state, internal energy, first and second laws, entropy and response functions. Application to heat engines and refrigerators. Free energies, Legendre transformations, changes of phase. Introduction to the Boltzmann factor and statistical mechanics.

Requirements: PHYS242

Offering Faculty: Faculty of Arts and Science

PHYS 414 Introduction to General Relativity Units: 3.00

Einstein's theory of gravity is developed from fundamental principles to a level which enables the student to read some of the current literature. Includes an introduction to computer algebra, an essential element of a modern introduction to Einstein's theory.

Requirements: Prerequisite PHYS 321 and (PHYS 312 or PHYS 317 or MATH 334).

Offering Faculty: Faculty of Arts and Science

PHYS 432 Electromagnetic Theory Units: 3.00

Electromagnetic theory and applications. Topics include: Maxwell's equations, gauge theory, relativistic transformations of Maxwell's equations, properties of waves in free space, dielectrics, conductors and ionized media, reflection and refraction at the surfaces of various media, propagation in metallic and dielectric waveguides, radiation of electromagnetic waves from charged particles and antennae.

Requirements: Prerequisite PHYS 239 and (MATH 221 or MATH 280) and (MATH 225 or MATH 231 or MATH 232). Equivalency PHYS 332.

Course Equivalencies: PHYS332, PHYS432

Offering Faculty: Faculty of Arts and Science

PHYS 435 Stellar Structure and Evolution Units: 3.00

This course provides a detailed account of the formation, structure, evolution and endpoints of stars. Topics include the HR diagram, nuclear energy generation, radiative transport and stellar model building, supernovae, white dwarfs, neutron stars, pulsars and black holes.

Requirements: Prerequisite PHYS 315.

Offering Faculty: Faculty of Arts and Science

PHYS 444 Advanced Quantum Physics Units: 3.00

This course covers perturbation theory, scattering theory and the addition of angular momentum. Special topics may include: many-electron systems, path integral formulation of quantum mechanics, entanglement and quantum computing, quantum optics.

Requirements: Prerequisite PHYS 345. Equivalency PHYS 426.

Course Equivalencies: PHYS426, PHYS444

Offering Faculty: Faculty of Arts and Science

PHYS 453 Advanced Physics Laboratory Units: 3.00

Advanced physics laboratory course providing students with experience in a range of experimental techniques and analysis. A selection of experiments are performed from fields including nuclear physics, applied physics, fluid mechanics, solid state physics, low-temperature physics and optics.

Learning Hours: 132 (76 Laboratory, 60 Private Study)

Requirements: Prerequisite PHYS 350/3.0 and (PHYS 344/3.0 or CHEM 313/3.0).

Offering Faculty: Faculty of Arts and Science

PHYS 454 Advanced Physics Design Project Units: 3.00

Groups of students in physics and engineering physics undertake a large design project of their choice that reflects and further develops their knowledge of physics. The students then build a prototype of their design to demonstrate the feasibility of the project within the design constraints.

Requirements: Prerequisite PHYS 350.

Offering Faculty: Faculty of Arts and Science

PHYS 460 Laser Optics Units: 3.00

Topics and applications in modern physical optics, culminating with the development of the laser and its current applications. Topics include: Gaussian beam propagation, optical resonators, Fourier optics, fiber optics, holography, light-matter interaction using classical and semi-classical models, and the basic theory and types of lasers.

Requirements: Prerequisite PHYS 239 and (PHYS 344 or CHEM 313). Corequisite PHYS 432.

Offering Faculty: Faculty of Arts and Science

PHYS 472 Statistical Mechanics Units: 3.00

Phase space, the ergodic hypothesis and ensemble theory. Canonical and grand canonical ensembles. Partition functions. Ideal quantum gases. Classical gases and the liquid-vapour transition. Introduction to techniques for interacting systems, including Monte Carlo simulations.

Requirements: Prerequisite (PHYS 213 or PHYS 313) and PHYS 344 and PHYS 372. Exclusion CHEM 412.

Offering Faculty: Faculty of Arts and Science

PHYS 479 High Performance Computational Physics Units: 3.00

This course teaches students how to use the tools of high performance computing facilities, including communications protocol for parallel computations. Students will employ these facilities and tools and use various numerical algorithms in the solution of physics problems.

Learning Hours: 120 (24 Lecture, 24 Tutorial, 72 Private Study)

Requirements: Prerequisite (PHYS 213 or PHYS 313) and PHYS 344. Corequisite PHYS 432.

Offering Faculty: Faculty of Arts and Science

PHYS 480 Solid State Physics Units: 3.00

A fundamental treatment of the properties of solids. Topics include: crystal structure, X-ray and neutron scattering, the reciprocal lattice, phonons, electronic energy bands, and the thermal, magnetic, optical and transport properties of solids.

Requirements: Prerequisite PHYS 345 or CHEM 313.

Offering Faculty: Faculty of Arts and Science

PHYS 483 Nanoscience and Nanotechnology Units: 3.00

An examination of the key ideas, techniques and technologies in the fields of nanoscience and nanotechnology. Emphasis will be placed on the physics involved, measurement techniques, and technological applications. Topics covered are selected from the following: electrical and optical properties of quantum dots, quantum wires and nanotubes; quantum information technology; mesoscopic electronics; nanostructures on surfaces; and scanning-probe and optical microscopy.

Requirements: Prerequisite ([PHYS 345 or CHEM 313] and PHYS 480) or permission of the Department.

Offering Faculty: Faculty of Arts and Science

PHYS 490 Nuclear and Particle Physics Units: 3.00

A systematic introduction to nuclear and particle physics for advanced physics students. Topics include basic nuclear properties: size, mass, decay and reactions; shell model of nuclear structure; magnetic moments; gamma and beta decay; quark model of elementary particles; and strong, electromagnetic and weak interactions.

Requirements: Prerequisite PHYS 345.

Offering Faculty: Faculty of Arts and Science

PHYS 491 Physics of Nuclear Reactors Units: 3.00

The objective of this course is the understanding of the fundamental physics associated with a nuclear reactor. Topics include a brief review of basic nuclear physics, neutron interactions and cross-sections, neutron diffusion, neutron moderation, theory of reactors, changes in reactivity, control of reactors. Offered in alternate years.

NOTE Manual: estimated cost \$15 to \$25 per manual.

Learning Hours: 120 (36 Lecture, 12 Tutorial, 72 Private Study)

Requirements: Prerequisite Level 3 or above and registration in a (PHYS, ASPH or MAPH Plan).

Offering Faculty: Faculty of Arts and Science

**PHYS 495 Introduction to Medical Physics Units: 3.00**

Topics include: the production and measurement of X-rays and charged particles for radiation therapy and nuclear medicine; interactions of radiation with matter and biological materials; interaction coefficients and radiation dosimetry; radiation safety; physics of medical imaging with examples from nuclear medicine, ultrasound and magnetic resonance imaging.

Requirements: Prerequisite Level 3 or above and registration in a (PHYS, ASPH or MAPH Plan).

Offering Faculty: Faculty of Arts and Science

PHYS 590 Research Thesis Units: 6.00

Investigation of a contemporary research topic in physics or astronomy under the supervision of a faculty member, and leading to a written thesis and an oral presentation of results.

Requirements: Prerequisite Level 4 or above and registration in a (PHYS, ASPH or MAPH Plan).

Offering Faculty: Faculty of Arts and Science

PHYS 594 Independent Study Units: 3.00

Exceptionally qualified students entering their third- or fourth-year may take a program of independent study provided it has been approved by the Department or Departments principally involved. The Department may approve an independent study program without permitting it to be counted toward a concentration in that Department. It is, consequently, the responsibility of students taking such programs to ensure that the concentration requirements for their degree will be met.

NOTE Requests for such a program must be received one month before the start of the first term in which the student intends to undertake the program.

Requirements: Prerequisite Permission of the Department or Departments principally involved.

Offering Faculty: Faculty of Arts and Science