

PHYSICS

About Physics

The Department of Physics currently has a faculty of approximately 40 members, including several holders of Canada Research Chairs and many other prestigious named Chairs. Additionally, we host an impressive number of postdoctoral fellows and research associates and run one of the largest and most vibrant graduate programs in North America. Graduate student enrolment is currently approximately 200.

Faculty members in the Department of Physics are recognized internationally for their excellence. Our members have received national and international prizes and fellowships including *Les Prix Du Québec*, Steacie Prize, Sloan Fellowships, NSERC, and many others. They are also in constant demand as reviewers and referees. Students who earn advanced degrees from the Department of Physics will not only get an excellent education, they will also receive valuable guidance and network contacts to help with subsequent career steps.

The Department offers full **M.Sc.** and **Ph.D.** degree programs in a wide range of disciplines, including:

- astrophysics;
- atmospheric physics;
- bio-physics;
- condensed-matter physics;
- high-energy physics;
- laser spectroscopy;
- material physics;
- non-linear dynamics and atmospheric physics;
- nuclear physics;
- statistical physics;
- medical-radiation physics.

Although most of the teaching and research facilities are located in the Ernest Rutherford Physics Building, the Department has space and research facilities in the Wong Materials Science Centre, adjacent to the Rutherford Building. Our groups also conduct research at the McGill University Health Centre (MUHC), the Jewish General Hospital, the Montreal Neurological Institute (MNI), and laboratories around the world—including Argonne, CERN, FermiLab, SLAC, TRIUMF, and KEK.

Departmental researchers enjoy technical support in the areas of engineering, electronics, and precision machining. The Department maintains an excellent conventional machine shop as well as the McGill Nanotools-Microfab facility. Most of the scientific computing is done with an extensive in-house network of powerful workstations and several Beowulf clusters.

Remote access to supercomputing sites in Canada and the United States is also possible including the McGill HPC super-computing facility which is a part of the nationwide network of high performance computing installations in Quebec.

The Department of Physics offers a competitive funding package for both local and international students.

Graduate students in the Department of Physics come from many different countries and cultural backgrounds, providing a stimulating cosmopolitan atmosphere in the Department. This, coupled with the

unique opportunities afforded by the city of Montreal, guarantees a quality of life that is second to none among Canadian universities. Please visit the Department of Physics Applications and Admissions page for more information.

Fields of Research

High-Energy Physics

Theoretical: The McGill high energy theorists have interests in a wide range of areas within quantum field theory, string theory, quantum gravity, and cosmology. Research areas of the high-energy theory faculty include applications of quantum field theory techniques to relativistic heavy ion collisions, baryogenesis, superstring cosmology, theory of cosmological perturbations, black hole physics, supergravity, three dimensional gravity, and various topics related to the physics and mathematics of superstring theory. The high-energy theorists have close connections to the nuclear theory group, the astrophysics group, the high-energy experimentalists, and to members of the Mathematics Department.

Experimental: The experimental high-energy physics group is engaged in a number of experiments at the research frontiers of the field, both in subatomic physics and in high-energy astrophysics. These include:

- Electron-positron collisions: a group works on the BaBar experiment at SLAC and the Belle-2 experiment at the KEK laboratory in Japan, with specific interest in CKM matrix elements and physics beyond the Standard Model through studies of rare decays, and on R&D for a future International Linear Collider, with interest in calorimeter development.
- Hadron-hadron collisions: A group is involved in major contributions to the energy frontier at CERN's LHC, with work on the High Level Trigger for the ATLAS experiment. Work also focuses on searches for new physics phenomena, precision physics of known Standard Model processes, development of the ATLAS experiment's trigger system, and direct contribution to the upgrade of the ATLAS detector.
- High-energy particle astrophysics: ground-based gamma-ray astronomy using the VERITAS telescope array and development of the next-generation detector.
- Underground physics: A group carries out experimental R&D with the aim of measuring, for the first time, the neutrinoless double-beta decay process with the EXO experiment.

Students at the M.Sc. and Ph.D. levels are offered a strong program of research in a challenging and rapidly advancing field. Short term master's projects are based mainly on instrumentation or data analysis conducted on campus, while Ph.D. research may involve an extended stay at one of the world's major research laboratories.

Nuclear Physics

Theoretical: Current research programs include transport equations for heavy ion collisions at intermediate energy; nuclear equation of state from heavy ion collisions; fragmentation at intermediate energy; electromagnetic probes in relativistic heavy ion collisions; effective Lagrangians for hadronic systems at finite temperature; and Quark-Gluon Plasma, QCD.

Experimental: Current research programs in experimental nuclear physics at McGill are focused on two main axes:

- The study of heavy-ion reactions at relativistic energies to determine the properties of nuclear matter at high temperatures and density. This program is being performed at the Brookhaven

National Laboratory, and at the Large Hadron Collider facility at CERN.

- The study of ground state properties of unstable nuclei using laser spectroscopy techniques and ion traps. This work is being carried out using the Canadian Penning trap facility at the Argonne National Laboratory, at the accelerator ISOLDE (CERN), and the ISAC facility at TRIUMF.

Furthermore, the Nuclear Physics Group has an active in-house research program that applies the ion trap and laser techniques to the detection of trace quantities of material and contaminants, and to ion spectroscopy.

Condensed Matter Physics and Biophysics

Theoretical: Current research programs involve the nonequilibrium, ab-initio modelling of molecular and nanoelectronic systems and devices; the study of quantum effects in interacting mesoscopic electron systems; nonequilibrium phenomena in extended systems and materials; and applications of statistical mechanics to problems in biophysics.

Experimental: Current research programs involve:

- the study of the time evolution of non-equilibrium systems via X-ray diffraction;
- fundamental quantum properties of strongly correlated systems at temperatures very near absolute zero;
- the study of nonequilibrium phase transformations and microstructure evolution in materials
- macromolecular interactions in living cells using single-photon and two-photon imaging;
- molecular electronics and nanoelectronic systems by scanning probe microscopy;
- dynamics and mechanical properties of soft matter systems and spatial organization and dynamics in living cells;
- mechanical behaviour of very small systems by high-resolution force microscopy;
- electronic properties that emerge at the limits of miniaturization and quantum computing;
- nuclear methods to study interactions in magnetic materials that lead to exotic magnetic ordering behaviour. This includes studies of novel materials such as carbon nanotubes, graphene, unconventional superconductors, quantum dots, heterostructures, amorphous systems, and spin glasses.

Astrophysics

Research in the astrophysics group covers a wide range of topics including cosmology, galaxy formation, high-energy astrophysics, and extrasolar planets. This involves observations at all wavelengths, from gamma rays and X-rays to sub-mm, infrared, and radio, using international observatories in space and on the ground. Experimental groups at McGill are involved in development and operation of ground-based high-energy gamma-ray observatories, and cosmic microwave background experiments. Theoretical work includes studies of how astrophysics and observational cosmology can experimentally determine the most important properties of dark matter and dark energy, studies of the diverse physics of neutron stars, and extrasolar planet formation.

Nonlinear Variability and Atmospheric Physics

This group studies nonlinear dynamical processes in the atmosphere and other geophysical systems, especially those associated with

turbulent, chaotic, and extremely variable behaviour. Emphasis is placed on multifractal analysis and modelling as well as the development of new theories and techniques covering wide ranges of scale in time and space. Data from a variety of in situ and remotely sensed sources are used. This includes satellite data of the Earth's atmosphere and surface as well as high-quality precipitation data from the McGill Radar Weather Observatory.

Medical Radiation Physics

The Medical Physics Unit is a teaching and research unit concerned with the application of physics and related sciences in medicine, especially (but not exclusively) in radiation medicine; i.e., radiation oncology, medical imaging, and nuclear medicine. The Unit's facilities are available for students to undertake a Ph.D. in Physics administered through the Department of Physics with a research emphasis on medical physics supervised, funded, and hosted by Medical Physics Unit PIs (principal investigators).

The research interests of Unit members include various aspects of medical imaging, including:

- 3D imaging;
- the development of new imaging modalities;
- applications of imaging in radiation therapy such as radiation dosimetry and solid state;
- nuclear cardiology; and
- applications of radiation biology to therapy.

Physics Admission Requirements and Application Procedures

Admission Requirements

M.Sc.

We normally require a background that is equivalent to our Physics Major (B.Sc.) (63 credits).

Ph.D.

The normal requirement is an M.Sc. in Physics or equivalent, but exceptional students may be considered for direct entry to the Ph.D. program. On the recommendation of the Departmental Graduate Committee, fast-tracking from the M.Sc. program into the Ph.D. program may be granted after one year, if:

- the student has fulfilled the M.Sc. coursework requirements, or;
- the Committee determines that the student qualifies based on the student's academic record.

All students who transfer to the Ph.D. program are required to fulfil Ph.D. coursework requirements in addition to the courses taken as an M.Sc. candidate.

Application Procedures

McGill's online application form for graduate program candidates is available at mcgill.ca/gradapplicants/apply.

See University Regulations & Resources > Graduate > Graduate Admissions and Application Procedures > Application Procedures for detailed application procedures.

Financial Assistance

Financial assistance will be offered to all students at the time of acceptance, if applicable. For more information, please visit our finance page: physics.mcgill.ca/grads/finance.html.

Additional Requirements

The items and clarifications below are additional requirements set by this department:

- two letters of reference;
- Physics CV;
- personal statement;
- thesis abstract or summary – optional;
- GRE – recommended but not required

A list of supporting documentation required by the University can be found at mcgill.ca/gradapplicants/apply/prepare/checklist/documents. International students must also demonstrate proficiency in English. Details are available at mcgill.ca/gradapplicants/international/apply/proficiency.

Application Dates and Deadlines

Application opening dates are set by Enrolment Services in consultation with Graduate and Postdoctoral Studies (GPS), while application deadlines are set by the Department of Physics and may be revised at any time. Applicants must verify all deadlines and documentation requirements well in advance on the appropriate McGill departmental website; please consult the list at mcgill.ca/gps/contact/graduate-program.

Information on application deadlines is available at mcgill.ca/gradapplicants/how-apply/application-steps/application-deadlines.

Please note, the Ph.D. program with a research emphasis on medical physics only accepts students in Fall.

Admission to graduate studies is competitive; accordingly, late and/or incomplete applications are considered only as time and space permit.

Available Programs

- Physics (Ph.D.)
- Physics (Thesis) (M.Sc.) (45 credits)

Program Overview

The **Master of Science (M.Sc.) Physics (Thesis)** program provides a comprehensive introduction to the academic, research, and practical aspects of physics. The primary goal of this program is to provide students with unique opportunities to learn fundamental research techniques in experimental and/or theoretical research, and objectively synthesize information from scientific literature. Each M.Sc. student chooses their preferred major research area and research supervisor. Thesis work is available in a broad range of sub-disciplines (see departmental website for details). Students wishing to continue to our doctoral program have the option, with supervisor approval, of transferring directly to the Ph.D., waiving the M.Sc. thesis submission.

The **Doctor of Philosophy (Ph.D.) Physics** provides all the tools required for a competitive career in academic settings, as well as in industry or other fields. The multidisciplinary nature of the Department exposes students to a vast array of research interests and experimental or theoretical approaches. Graduate research activities leading to

the presentation of a Ph.D. thesis involve original work, with distinct contributions to knowledge. Our graduate program offers training in a unique and multidisciplinary environment in Canada's top university and may involve an extended stay at one of the world's major research laboratories.

Location

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