The Departments of Physics at the Universities of Guelph and Waterloo offers MSc and PhD degrees in the following fields:

- Astrophysics and Gravitation
- Atomic, Molecular and Optical Physics
- Biophysics
- Chemical Physics
- Condensed Matter and Material Physics
- Industrial and Applied Physics
- Subatomic Physics
- Quantum Computing

The University of Guelph and the University of Waterloo have a joint program in which graduate courses are taught by instructors from both universities. Students are registered at the university their advisor is located. A student comes under the general regulations of the university at which he or she is registered, and the degree is granted by that university.

**Administrative Staff**

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This list may include Regular Graduate Faculty, Associated Graduate Faculty and/or Graduate Faculty from other universities.

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Graduate Faculty Other University

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Graduate Faculty Other University

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Graduate Faculty Other University

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Graduate Faculty Other University

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Graduate Faculty Other University

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Associated Graduate Faculty

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Graduate Faculty Other University

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Graduate Faculty Other University

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B.Sc., BA Moorhead, PhD Manitoba - Professor Emeritus

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Graduate Faculty

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Graduate Faculty Other University

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Graduate Faculty Other University

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Graduate Faculty Other University

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Graduate Faculty

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Graduate Faculty

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B.Sc., PhD McMaster - Professor
Graduate Faculty

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Graduate Faculty Other University

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Huan Yang
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Graduate Faculty Other University

Na Young Kim
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Graduate Faculty Other University

MSc Program
The MSc program is offered in the following fields:
1. astrophysics and gravitation;
2. atomic, molecular and optical physics;
3. biophysics;
4. chemical physics;
5. condensed matter and material physics;
6. industrial and applied physics;
7. subatomic physics; and
8. quantum computing.

Admission Requirements
Application for admission should be made as early as possible using on-line application methods described on the web-site https://www.physics.uoguelph.ca/graduate-studies/graduate-studies-in-physics/how-to-apply/. Successful applicants are encouraged to start their graduate studies in May or September, but a January starting date is possible. Program offices should be consulted for admission deadlines.

The admission requirements are as follows:
• An honours BSc degree in physics (or equivalent) with at least a B standing (75%) from a recognized university.
• Three letters of reference, two of which normally are from academic sources.
• Proof of competency in English (for applicants whose prior education was in a language other than English). See the University regulations on English Language Proficiency Certification.
• GRE Physics Subject Test score for all applicants who have received their degree in a country where English is not the primary language.

An MSc student in this program who shows a particular aptitude for research and has a superior record in fourth-year undergraduate and three one-term graduate courses may be permitted, upon recommendation of the advisor and with the approval of the coordinating committee, to transfer into the PhD program without completing an MSc thesis.

For all students one of the courses must include at least one of the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS*7010</td>
<td>Quantum Mechanics I</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7030</td>
<td>Quantum Field Theory</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7040</td>
<td>Statistical Physics I</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7060</td>
<td>Electromagnetic Theory</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7810</td>
<td>Fundamentals of Astrophysics</td>
<td>0.50</td>
</tr>
</tbody>
</table>

An average of at least 70% must be obtained in the required courses. A minimum grade of 65% is required for a pass in each course. No more than two courses, of the first four taken, can have a grade of less than 70%. If a student does not meet these minimum grade requirements, or receives a failing grade in any course, they may be required to withdraw from the program.

Course Work and Major Research Project (MRP)
Seven one-term courses (0.50 unit weight) acceptable for graduate credit, plus a project course summarized in a report, are required. The project must be approved by the student's advisor and the report read and approved by the advisor and one other faculty member. At least four of the seven courses must be physics graduate level courses.

Two of the seven courses may be upper level undergraduate courses approved by the student's advisory committee and the Graduate Program Coordinator. If it is a physics course, it must be at the fourth-year level. This program is recommended for those planning careers requiring a broad non-specialized knowledge of physics (for example, high school teaching).

PhD Program
The PhD program is research-based and offered in the fields of:
1. astrophysics and gravitation;
2. atomic, molecular and optical physics;
3. biophysics;
4. chemical physics;
5. condensed matter and material physics;
6. industrial and applied physics;
7. subatomic physics; and
8. quantum computing.

Admission Requirements
There are three pathways for admission to the PhD program:
1. An MSc degree in physics from an approved university or college with at least a B standing (75%) is normally required for entrance into the PhD program. Other requirements are the same as those described above for the MSc program (see web-site https://www.physics.uoguelph.ca/graduate-studies/graduate-studies-in-physics/how-to-apply (https://www.physics.uoguelph.ca/graduate-studies/graduate-studies-in-physics/how-to-apply/)).
2. Students with an undergraduate degree in Physics may apply for admission directly to the PhD program. Successful applicants will have an outstanding academic record, breadth of knowledge in physics, previous research experience, and strong letters of recommendation.
3. Students wishing to be considered for transfer to a PhD program prior to completion of the MSc program must request the transfer up to 3 full-time terms after initial registration and have an excellent academic record as well as a strong aptitude for research.

Program Requirements
Three core courses or their equivalent must be completed by end of the first year of the PhD program. This requirement may be satisfied, in full or in part, by courses taken during the M.Sc. The core courses for the program are:

<table>
<thead>
<tr>
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<th>Title</th>
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</tr>
</thead>
<tbody>
<tr>
<td>PHYS*7010</td>
<td>Quantum Mechanics I</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7030</td>
<td>Quantum Field Theory</td>
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</tr>
<tr>
<td>PHYS*7040</td>
<td>Statistical Physics I</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7060</td>
<td>Electromagnetic Theory</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7670</td>
<td>Introduction to Quantum Information Processing</td>
<td>0.50</td>
</tr>
<tr>
<td>PHYS*7810</td>
<td>Fundamentals of Astrophysics</td>
<td>0.50</td>
</tr>
</tbody>
</table>

One of the core courses must include PHYS*7010 Quantum Mechanics I, PHYS*7040 Statistical Physics I, or PHYS*7060 Electromagnetic Theory. Exception: Biophysics students within the PhD program are required to take only one core course by the completion of the first year of the program, which must include one of PHYS*7010 Quantum Mechanics I, PHYS*7040 Statistical Physics I, or PHYS*7060 Electromagnetic Theory.

A minimum of two one-term courses are required to be taken for the PhD degree, which may include or be in addition to the core courses required as specified above. One of the required courses may be an undergraduate course outside the student's main field of study and must be approved by the student's advisory committee and the Graduate Program Coordinator. No undergraduate course in physics may be taken for credit. No courses taken for MSc credit may be used to satisfy the minimum course requirement. However, courses taken during the MSc program and in excess of those required for the MSc program will be allowed for PhD credit. The extra courses must be identified prior to admission to the PhD program.

An average of at least 70% must be obtained in the required courses. A minimum grade of 65% is required for a pass in each course. No more than two courses, of the first four taken, can have a grade of less than 70%. If a student does not meet these minimum grade requirements, or receives a failing grade in any course, they may be required to withdraw from the program.

Students who transfer to the PhD, or who enter the PhD directly, will need to complete the course work requirements of both the MSc and PhD degrees, a total of six one-term graduate courses. Three of the core courses including one of PHYS*7010 Quantum Mechanics I, PHYS*7040 Statistical Physics I or PHYS*7060 Electromagnetic Theory will have been taken by the end of the first year of the PhD program.

Interdepartmental Programs
Biophysics Interdepartmental Group
The Department of Physics participates in the MSc/PhD programs in biophysics. Please consult the Biophysics (calendar.uoguelph.ca/graduate-calender/graduate-programs/biophysics/) listing for a detailed description of the graduate programs offered by the Biophysics Interdepartmental Group.

Courses
Unless otherwise indicated, courses are offered on an alternate year basis and as requested.

PHYS*6010 PSI Quantum Field Theory I Unspecified [0.50]
Canonical quantization of fields, perturbation theory, derivation of Feynman diagrams, applications in particle and condensed matter theory, renormalization in phi^4.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6020 PSI Statistical Physics Unspecified [0.50]
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6030 PSI Quantum Field Theory II Unspecified [0.50]
Feynman Path Integral, abelian and nonabelian gauge theories and their quantization, spontaneous symmetry breaking, nonperturbative techniques: lattice field theory, Wilsonian renormalization.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6040 PSI Relativity Unspecified [0.50]
Special relativity, foundations of general relativity, Riemannian geometry, Einstein’s equations, FRW and Schwarzschild geometries and their properties.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6050 PSI Quantum Theory Unspecified [0.50]
Department(s): Department of Physics
Location(s): Waterloo Campus
PHYS*6060  PSI Information and Data Analysis  Unspecified  [0.50]
Probability, entropy, Bayesian inference and information theory. Maximum
likelihood methods, common probability distributions, applications to real
data including Monte Carlo methods.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6070  PSI Dynamical Systems  Unspecified  [0.50]
Maps, flows, stability, fixed points, attractors, chaos, bifurcations,
and Hamiltonian systems, Liouville, measure, Poincare theorem, integrable systems with examples.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6080  PSI Computation  Unspecified  [0.50]
Common algorithms for ode and pde solving, with numerical analysis.
Common tasks in linear algebra. Focus on how to write a good code, test
it, and obtain a reliable result. Parallel programing.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6200  PSI Cosmology  Unspecified  [0.25]
FRW metric, Hubble expansion, dark energy, dark matter, CMB,
and structure formation and comparison to observations, cosmic
microwave background anisopropies, inflation and observational tests.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6210  PSI String Theory  Unspecified  [0.25]
Superstring spectrum in 10d Minkowski, as well as simple toroidal and
orbiold compactifications. T-duality, D-branes, tree amplitudes. Construct
some simple unified models of particle physics. Motivate the 10- 11-
dimensional supergravities. Simple supergravity solutions and use these
to explore some aspects of adS/CFT duality.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6230  PSI Mathematical Physics Topics  Unspecified  [0.25]
Differential forms, de Rham cohomology, differential topology and
characteristic classes, monopoles and instantons, Kahler manifolds,
Dirac equations, zero modes and index theorems.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6350  PSI Quantum Information Review  Unspecified  [0.25]
Review of selected topics in Quantum Information.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6360  PSI Gravitational Physics Review  Unspecified  [0.25]
Review of selected topics in Gravitational Physics.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6370  PSI Condensed Matter Theory  Unspecified  [0.25]
Review of selected topics in Condensed Matter Theory.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6380  PSI Quantum Gravity  Unspecified  [0.25]
Review of selected topics in Quantum Gravity.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6390  PSI Foundations of Quantum Theory  Unspecified  [0.25]
Review of selected topics in Foundations of Quantum Theory.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6400  PSI Explorations in Particle Physics  Unspecified  [0.25]
Review of selected topics in Particle Physics.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6410  PSI Explorations in Quantum Information  Unspecified  [0.25]
Review of selected topics in Quantum Information.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6420  PSI Explorations in Gravitational Physics  Unspecified  [0.25]
Review of selected topics in Gravitational Physics.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6430  PSI Explorations in Condensed Matter Theory  Unspecified  [0.25]
Review of selected topics in Condensed Matter Theory.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6440  PSI Explorations in Quantum Gravity  Unspecified  [0.25]
Review of selected topics in Quantum Gravity.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6450  PSI Explorations in Foundations of Quantum Theory  Unspecified  [0.25]
Review of selected topics in Foundations of Quantum Theory.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6460  PSI Explorations in Particle Physics  Unspecified  [0.25]
Review of selected topics in Particle Physics.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6470  PSI Explorations in String Theory  Unspecified  [0.25]
Review of selected topics in String Theory.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6480  PSI Explorations in Complex Systems  Unspecified  [0.25]
Review of selected topics in Complex Systems.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*6490  PSI Explorations in Cosmology  Unspecified  [0.25]
Review of selected topics in Cosmology.
Department(s): Department of Physics
Location(s): Waterloo Campus

PHYS*7010  Quantum Mechanics I  Unspecified  [0.50]
Review of formalism of nonrelativistic quantum mechanics including
symmetries and invariance. Approximation methods and scattering
theory. Elementary quantum theory of radiation. Introduction to one-
particle relativistic wave equations.
Offering(s): Annually
Department(s): Department of Physics
Location(s): Guelph
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS*7020</td>
<td>Quantum Mechanics II Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7030</td>
<td>Quantum Field Theory Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7040</td>
<td>Statistical Physics I Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7050</td>
<td>Statistical Physics II Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7060</td>
<td>Electromagnetic Theory Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7080</td>
<td>Applications of Group Theory Unspecified</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7090</td>
<td>Green's Function Method Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7100</td>
<td>Atomic Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7120</td>
<td>Special Topics in Theoretical Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7130</td>
<td>Molecular Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7140</td>
<td>Nonlinear Optics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7150</td>
<td>Nuclear Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7160</td>
<td>Special Topics in Subatomic and Nuclear Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7170</td>
<td>Intermediate and High Energy Physics Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7180</td>
<td>Special Topics in Subatomic and Nuclear Physics Unspecified [0.25]</td>
<td>Department of Physics</td>
</tr>
<tr>
<td>PHYS*7310</td>
<td>Solid State Physics I Unspecified [0.50]</td>
<td>Department of Physics</td>
</tr>
</tbody>
</table>
**PHYS*7320** Solid State Physics II  
**Unspecified [0.50]**  
Transport properties; optical properties; magnetism; superconductivity; disordered systems.  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7330** Special Topics in Theoretical Condensed Matter  
**Physics Unspecified [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7340** Special Topics in Experimental Physics  
**Unspecified [0.50]**  
A modular course in which each module deals with an established technique of experimental physics. Four modules will be offered during the Winter and Spring semesters, but registration and credit will be in the spring semester. Typical topics include: neutron diffraction, light scattering, acoustics, molecular beams, NMR, surface analysis, etc.  
**Offering(s):** Annually  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7450** Special Topics in Optical Electronics  
**Unspecified [0.50]**  
Optoelectronic component fabrication, light propagation in linear and nonlinear media, optical fiber properties, electro-optic and acousto-optic modulation, spontaneous and stimulated emission, semiconductor lasers and detectors, noise effects in fiber systems.  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7470** Optical Electronics  
**Unspecified [0.50]**  
Optoelectronic component fabrication, light propagation in linear and nonlinear media, optical fiber properties, electro-optic and acousto-optic modulation, spontaneous and stimulated emission, semiconductor lasers and detectors, noise effects in fiber systems.  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7510** Clinical Applications of Physics in Medicine  
**Unspecified [0.50]**  
This course provides an overview of the application of physics to medicine. The physical concepts underlying the diagnosis and treatment of disease will be explored. Topics will include general imaging principles such as resolution, intensity, and contrast; x-ray imaging and computed tomography; radioisotopes and nuclear medicine, SPECT and PET; magnetic resonance imaging; ultrasound imaging and radiation therapy. Offered in conjunction with PHYS*4070. Extra work is required of graduate students.  
**Restriction(s):** Credit may be obtained for only one of PHYS*4070 or PHYS*7510.  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7520** Molecular Biophysics  
**Unspecified [0.50]**  
Physical methods of determining macromolecular structure: energetics, intramolecular and intermolecular forces, with application to lamellar structures, information storage, DNA and RNA, recognition and rejection of foreign molecules. Offered in conjunction with PHYS*4540. Extra work is required of graduate students.  
**Restriction(s):** Credit may be obtained for only one of PHYS*4540 or PHYS*7520  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7540** Special Topics in Biophysics  
**Unspecified [0.50]**  
Offered on demand  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7570** Special Topics in Biophysics  
**Unspecified [0.25]**  
Offered on demand  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7670** Introduction to Quantum Information Processing  
**Fall Only [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph, Waterloo Campus  

**PHYS*7680** Special Topics in Quantum Information Processing  
**Unspecified [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph, Waterloo Campus  

**PHYS*7690** Special Topics in Quantum Information Processing  
**Unspecified [0.25]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7710** Special Lecture and Reading Course  
**Unspecified [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7730** Special Topics in Physics  
**Unspecified [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7750** Interinstitution Exchange  
**Unspecified [0.50]**  
At the GWPI director's discretion, a PhD or MSc student may receive credit for a term of specialized studies at another institution. Formal evaluation is required.  
**Restriction(s):** Instructor consent required.  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7760** Special Topics in Physics  
**Unspecified [0.50]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7770** Special Topics in Physics  
**Unspecified [0.25]**  
**Department(s):** Department of Physics  
**Location(s):** Guelph  

**PHYS*7810** Fundamentals of Astrophysics  
**Unspecified [0.50]**  
The fundamental astronomical data: techniques to obtain it and the shortcomings present. The classification systems. Wide- and narrow-band photometric systems. The intrinsic properties of stars: colours, luminosities, masses, radii, temperatures. Variable stars. Distance indicators. Interstellar reddening. Related topics.  
**Department(s):** Department of Physics  
**Location(s):** Guelph, Waterloo Campus
PHYS*7840 Advanced General Relativity Winter Only [0.50]
Department(s): Department of Physics
Location(s): Guelph

PHYS*7850 Quantum Field Theory for Cosmology Unspecified [0.50]
Introduction to scalar field theory and its canonical quantization in flat and curved spacetimes. The flat space effects of Casimir and Unruh. Quantum fluctuations of scalar fields and of the metric on curved space-times and application to inflationary cosmology. Hawking radiation.
Prerequisite(s): PHYS*7010
Department(s): Department of Physics
Location(s): Guelph, Waterloo Campus

PHYS*7860 General Relativity for Cosmology Unspecified [0.50]
Department(s): Department of Physics
Location(s): Guelph, Waterloo Campus

PHYS*7870 Cosmology Unspecified [0.50]
Friedmann-Robertson-Walker metric and dynamics; big bang thermodynamics; nucleosynthesis; recombination; perturbation theory and structure formation; anisotropies in the Cosmic Microwave Background; statistics of cosmological density and velocity fields; galaxy formation; inflation.
Department(s): Department of Physics
Location(s): Guelph

PHYS*7880 Special Topics in Astrophysics Unspecified [0.50]
Offered on demand
Department(s): Department of Physics
Location(s): Guelph

PHYS*7890 Special Topics in Astrophysics Unspecified [0.25]
Offered on demand
Department(s): Department of Physics
Location(s): Guelph

PHYS*7900 Special Topics in Gravitation and Cosmology Unspecified [0.50]
Department(s): Department of Physics
Location(s): Guelph

PHYS*7910 Special Topics in Gravitation and Cosmology Unspecified [0.25]
Department(s): Department of Physics
Location(s): Guelph

PHYS*7970 MSc Project Unspecified [1.00]
Study of a selected topic in physics presented in the form of a written report. For students whose MSc program consists entirely of courses
Department(s): Department of Physics
Location(s): Guelph