DOCTORATE IN PHILOSOPHY PHYSICS

Summary

• Degree offered: Doctorate in Philosophy (PhD)
• Registration status option: Full-time
• Language of instruction: English

Most of the requirements of this program must be fulfilled in English. Research activities may be conducted in English or in French, or in both languages, depending on the main language of the professor and of the members of the research group.

• Program option (expected duration of the program):
  • with thesis (16 full-time terms; 64 consecutive months)
• Academic units: Faculty of Science (https://science.uottawa.ca/en), Department of Physics (https://science.uottawa.ca/physics), Ottawa-Carleton Institute for Physics (http://ocip.ca).

Program Description
Ottawa-Carleton Institute for Physics

Established in 1983, the Ottawa-Carleton Institute for Physics (OCIP) combines the research strengths of the University of Ottawa and Carleton University. The Institute offers graduate programs leading to the master’s (MSc) and doctoral (PhD) degrees in Physics.

Research facilities are shared between the two campuses. Students have access to the professors, courses and facilities at both universities; however, they must enroll at the “home university” of the thesis supervisor.

Main Areas of Research

• Condensed matter
• High energy physics
• Biological physics
• Medical physics
• Photonics

Other Programs Offered Within the Same Discipline or in a Related Area

• Master of Science Physics (MSc)
• Master of Science Physics Specialization in Science, Society and Policy (MSc)

Fees and Funding

• Program fees:
The estimated amount for university fees (https://www.uottawa.ca/university-fees) associated with this program are available under the section Finance your studies (http://www.uottawa.ca/graduate-studies/programs-admission/finance-studies).

International students enrolled in a French-language program of study may be eligible for a differential tuition fee exemption (https://www.uottawa.ca/university-fees/differential-tuition-fee-exemption).

• To learn about possibilities for financing your graduate studies, consult the Awards and financial support (https://www.uottawa.ca/graduate-studies/students/awards) section.

Notes

• Programs are governed by the general regulations (http://www.uottawa.ca/graduate-studies/students/general-regulations) in effect for graduate studies.
• In accordance with the University of Ottawa regulation, students have the right to complete their assignments, examinations, research papers, and theses in French or in English.

Program Contact Information
Graduate Studies Office, Faculty of Science (https://science.uottawa.ca/en/faculty-services/graduate-studies)
30 Marie-Curie Street, Room 181
Ottawa, Ontario, Canada
K1N 6N5

Tel.: 613-562-5800 ext. 3145
Email: gradsci@uOttawa.ca

Twitter | Faculty of Science (https://twitter.com/uOttawaScience)
Facebook | Faculty of Science (https://www.facebook.com/uOttawaScience)

Admission Requirements

For the most accurate and up to date information on application deadlines, language tests and other admission requirements, please visit the specific requirements (http://www.uottawa.ca/graduate-studies/programs-admission/apply/specific-requirements) webpage.

To be eligible, candidates must:

• Be the holder of a master’s degree in physics (or equivalent) with a minimum average of 75% (B+).

Note: International candidates must check the admission equivalencies (https://www.uottawa.ca/graduate-studies/international/study-uottawa/admission-equivalencies) for the diploma they received in their country of origin.

• Demonstrate a good academic performance in previous studies as shown by official transcripts, research reports, abstracts or any other documents demonstrating research skills.
- Pay the $100 ($CDN non-refundable) application fee.
- Meet the funding requirements.
  Note: International students must provide proof of financial support: i.e., a stipend provided by a supervisor as well as a combination of awards and/or trust funds.
- Identify at least one professor who is willing to supervise your research and thesis.
  - We recommend that you contact potential thesis supervisors as soon as possible.
  - To register, you need to have been accepted by a thesis supervisor.
  - The supervisor’s name is required at the time of application.

**Language Requirements**

Applicants must have a good knowledge of either English or French and a good ability to write in English.

Applicants whose first language is neither French nor English must provide proof of proficiency in the language of instruction.

**Language tests recognized by the University of Ottawa:**

- TOEFL: 550 (paper-based); 79-80 (internet-based); or
- IELTS: Overall 6.5 – Individual 5.0 (paper-based or internet-based); or
- An equivalent language test (http://www.uottawa.ca/graduate-studies/programs-admission/apply/required-documents).

Note: Candidates are responsible for any fees associated with the language tests.

**Notes**

- The admission requirements listed above are minimum requirements and do not guarantee admission to the program.
- Admissions are governed by the general regulations (http://www.uottawa.ca/graduate-studies/students/general-regulations) in effect for graduate studies.

**Documents Required for Admission**

In addition to the documents required (http://www.uottawa.ca/graduate-studies/programs-admission/apply/required-documents) for graduate and postdoctoral studies, candidates must submit the following documents:

- A resume
- A letter of intent outlining your professional goals and proposed research area.
- Two confidential letters of recommendation from professors who have known the applicant and are familiar with their work.

You are strongly encouraged to contact your referee(s) prior to submitting your application in order to confirm their email address and their availability to complete your letter of recommendation.

- Transcripts from all universities attended.
  - You must submit official transcripts from all the universities you have attended.
    This applies to all courses and programs at any university you attended, including regular programs (completed or not), exchanges, letters of permission, online or correspondence courses, courses taken as a special student or visiting student, etc.
  - If the transcript and degree certificate are not in English or French, a certified translation (signed and stamped/sealed) must be submitted.

Note: Documents that are not required for admission will not be consulted, conserved or returned to the student. These documents will be destroyed according to our administrative procedures.

**Fast-Track from Master’s to PhD**

Students enrolled in the MSc in physics at the University of Ottawa may be eligible to fast-track directly into the doctoral program without writing a master’s thesis, provided the following conditions are met:

- Achievement of an A- average in the last two years of undergraduate studies;
- Completion of at least two graduate courses (6 units) with a grade of A- or better in each;
- Satisfactory progress in the research program;
- Written recommendation by the supervisor;
- Approval by the graduate studies committee.

Notes:

- The transfer must take place within sixteen months of initial enrollment in the master’s. Please note that the minimal admission average requirements for the doctoral program must also be met.
- All of the admission requirements of the doctoral program must also be met.

**Information about how to apply to this program is available under the Apply Now (http://www.uottawa.ca/graduate-studies/programs-admission/apply/#apply-now) section.**

Students should complete and submit their online application with supporting documentation (if applicable) by the deadline indicated above. The supporting documentation should be sent by e-mail attachment, regular mail, or in person.

**Program Requirements**

**Doctorate**

The Department may require students to take additional courses, depending on their backgrounds.

Students must meet the following requirements:

<table>
<thead>
<tr>
<th>Compulsory Courses</th>
<th>12 Units</th>
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<tr>
<td>12 optional course units in physics (PHY) at the graduate level</td>
<td>12 Units</td>
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</table>

<table>
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<tr>
<th>Comprehensive Examination</th>
<th>0 Unit</th>
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<tbody>
<tr>
<td>PHY 9998 Comprehensive Examination (PhD)</td>
<td>0 Unit</td>
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<table>
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<tr>
<th>Thesis</th>
<th>0 Unit</th>
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<tbody>
<tr>
<td>PHY 9999 PhD Thesis</td>
<td>0 Unit</td>
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Note(s)

1. The optional course units may be selected in related disciplines approved by the Department of Physics.
For more information, refer to the list of faculty members and their research fields on Uniweb.

IMPORTANT: Candidates and students looking for professors to supervise their thesis or research project can also consult the website of the faculty or department (https://www.uottawa.ca/graduate-studies/students/academic-unit-contact-information) of their program of choice. Uniweb does not list all professors authorized to supervise research projects at the University of Ottawa.

Courses
Not all of the listed courses are given each year. The course is offered in the language in which it is described.

Course codes in parentheses are for Carleton University. A 3-unit course at the University of Ottawa is equivalent to a 0.5-unit course at Carleton University.

**PHY 5100 Solid State Physics I (3 units)**
Periodic structures. Phonons and specific heat. Electron states and various methods of energy band calculation. Cohesion of solids. Electron-electron interaction. Optical properties. This course is equivalent to PHYJ 5401 at Carleton University.

Course Component: Lecture

**PHY 5110 Solid State Physics II (3 units)**
Elements of group theory. Measuring the Fermi surface. One electron dynamics. k.p method. Impurities. Quantum wells. Diamagnetism, paramagnetism and magnetic ordering. Superconductivity. This course is equivalent to PHYJ 5402 at Carleton University.

Course Component: Lecture

**PHY 5112 Physics of Medical Imaging (3 units)**
Physical foundation of, and recent developments in, transmission x-ray imaging, computerized tomography, nuclear medicine, magnetic resonance imaging, and ultrasound, for the imaging physics specialist. Imaging system performance: contrast, resolution, modulation transfer function, signal-to-noise ratio, detective quantum efficiency. Essentials of image display and processing. This course is equivalent to PHYS 5204 at Carleton University.

Course Component: Lecture

**PHY 5130 Experimental Characterization Techniques in Materials Science, Physics, Chemistry, and Mineralogy (3 units)**
Survey of experimental techniques used in materials science, condensed matter physics, solid state chemistry, and mineralogy to characterize materials and solid substances. Diffraction (X-ray diffraction, neutron diffraction...). Spectroscopy (infra-red spectroscopy, Raman spectroscopy, nuclear magnetic resonance, Mössbauer spectroscopy, electron spin resonance...). Microscopy and imaging (scanning electron microscopy, transmission electron microscopy, optical microscopy, magnetic resonance imaging...). Other analytic techniques (thermal analysis, wet chemistry, bulk thermodynamic properties, linear response and dc susceptibility...). This course is equivalent to PHYJ 5001 at Carleton University.

Course Component: Lecture

**PHY 5140 Methods in Theoretical Physics I (3 units)**
This course is equivalent to PHYS 5801 at Carleton University.

Course Component: Lecture

**PHY 5141 Methods in Theoretical Physics II (3 units)**
This course is equivalent to PHYS 5802 at Carleton University.

Course Component: Lecture
PHY 5151 Type I and II Superconductors (3 units)
Flux flow and flux cutting phenomena. Clem general critical state model. Flux quantization, Abrikosov vortex model and Ginzburg-Landau theory. Superconducting tunneling junctions (Giaever and Josephson types). High Tc superconductivity. This course is equivalent to PHYJ 5403 at Carleton University.
Course Component: Lecture
Prerequisite: PHY 4370

PHY 5161 Medical Radiation Physics (3 units)
This course is equivalent to PHYS 5203 at Carleton University.
Course Component: Lecture

PHY 5163 Radiation Protection (2 units)
This course is equivalent to PHYS 5208 at Carleton University.
Course Component: Lecture

PHY 5164 Medical Radiotherapy Physics (3 units)
This course is equivalent to PHYS 5206 at Carleton University.
Course Component: Lecture

PHY 5165 Radiobiology (3 units)
This course is equivalent to PHYS 5207 at Carleton University.
Course Component: Lecture

PHY 5166 Medical Physics Practicum (3 units)
This course is equivalent to PHYS 5209 at Carleton University.
Course Component: Lecture

PHY 5167 Advanced Topics in Medical Physics (3 units)
Topics may include medical imaging physics, cancer therapy physics, medical biophysics, or radiation protection and health physics. Topics vary from year to year.
Course Component: Lecture
Prerequisites: PHY 5161 plus, as appropriate to the topic offered, at least one of PHY 5112, PHY 5164, PHY 5165.

PHY 5168 Anatomy and Physiology for Medical Physicists
Overview of human anatomy and physiology as background for the application of physics to cancer therapy and medical imaging. Anatomy as depicted by imaging technologies such as CT, MRI, and radiography will be emphasized. Graded S (Satisfactory) or NS (Not satisfactory).
Course Component: Lecture
Prerequisite: Enrolment in the graduate field of medical physics.

PHY 5170 Advanced Quantum Mechanics I (3 units)
Review of operators, motion in a general field and angular momentum. Identical particles and exchange, two electron atoms, Hartree-Fock and statistical models of many particle systems. Angular momentum, Clebsch-Gordan coefficients and scattering theory.
Course Component: Lecture
Prerequisite: PHY 4370.

PHY 5311 Quantum Optics I (3 units)
Classical and semi-classical light-matter interaction; gauges and energy conservation; two level systems in the resonant, under-resonant and over-resonant limit; time-dependent perturbation theory and Fermi's golden rule; semi-classical laser theory; Landau Zener tunneling and multi-photon transitions; tunnel ionization and multi-photon ionization. This course is equivalent to PHYJ 5311 at Carleton University.
Course Component: Lecture

PHY 5312 Quantum Optics II (3 units)
Quantum light-matter interaction; quantization of the light field and of Schrödinger equation; number states and coherent states; photon emission and absorption; two-photon decay; photoelectric effect; Lamb shift, line-width and renormalization; Casimir effect; multi-photon processes; density operator; quantum theory of decay; quantum laser theory. This course is equivalent to PHYJ 5312 at Carleton University.
Course Component: Lecture

PHY 5318 Modern Optics (3 units)
Electromagnetic wave propagation; reflection, refraction; Gaussian beams; guided waves. Laser theory: stimulated emission, cavity optics, gain and bandwidth, atomic and molecular lasers. Mode locking, Q switching. Diffraction theory, coherence, Fourier optics, holography, laser applications. Optical communication systems, nonlinear effects: devices, fiber sensors, integrated optics.
Course Component: Lecture

PHY 5320 Introduction to the Physics of Macromolecules (3 units)
The chemistry of macromolecules and polymers; random walks and the static properties of polymers; experimental methods; the Rouse model and single chain dynamics; polymer melts and viscoelasticity; the Flory-Huggins theory; the reptation theory; computer simulation algorithms; biopolymers and copolymers. This course is equivalent to PHYJ 5508 at Carleton University.
Course Component: Lecture

PHY 5322 Biological Physics (3 units)
Biological phenomena studied using techniques of physics. Key components of cells. Physical concepts relevant to cellular phenomena: Brownian dynamics, fluids, suspensions, entropy driven phenomena, chemical forces and self-assembly. Biological molecules. Enzymes. Molecular motors. Nerve impulses. Also offered, with different requirements, as PHY 4322. Courses PHY 4322, PHY 5322 cannot be combined for units. This course is equivalent to PHYJ 5508 at Carleton University.
Course Component: Lecture
Exclusion: PHY 4322.

PHY 5330 Fiber Optics Communications (3 units)
Course Component: Lecture
PHY 5347 Physics, Chemistry and Characterization of Mineral Systems (3 units)
The materials science of mineral systems such as the network and layered silicates. In-depth study of the relations between mineralogically relevant variables such as atomic structure, crystal chemistry, site populations, valence state populations, crystallization conditions, etc. Interpretation and basic understanding of key characterization tools such as microprobe analysis, Mössbauer spectroscopy, x-ray diffraction and optical spectroscopy. This course is equivalent to PHYJ 5509 at Carleton University.

Course Component: Lecture
Prerequisites: PHY 4370 and PHY 3355.

PHY 5361 Nonlinear Dynamics in the Natural Sciences (3 units)
A multidisciplinary introduction to nonlinear dynamics with emphasis on the techniques of analysis of the dynamic behaviour of physical systems. Basic mathematical concepts underlying nonlinear dynamics, including differential and difference equations, Fourier series and data analysis, stability analysis, Poincaré maps, local bifurcations, routes to chaos and statistical properties of strange attractors. Applications of these concepts to specific problems in the natural sciences such as condensed matter physics, molecular physics, fluid mechanics, dissipative structures, evolutionary systems, etc. This course is equivalent to PHYJ 5102 at Carleton University.

Course Component: Lecture

PHY 5362 Computational Methods in Material Sciences (3 units)
Introduction to modern computational techniques used in material science research. Classical molecular dynamics, classical and quantum Monte Carlo methods, plane-wave based electronic band structure calculations, Carr-Parrinello quantum molecular dynamics. Applications to condensed matter systems: basic simulation techniques, force-field based methods in the study of thermodynamic and physical properties of solids, first-principles quantum mechanical methods. This course is equivalent to PHYJ 5006 at Carleton University.

Course Component: Lecture

PHY 5378 Semiconductor Physics I (3 units)
Brillouin zones and band theory. E-k diagram, effective mass tensors, etc. Electrical properties of semiconductors. This course is equivalent to PHYJ 5407 at Carleton University.

Course Component: Lecture

PHY 5381 Semiconductor Physics II: Optical Properties (3 units)

Course Component: Lecture
Prerequisite: PHY 4380 or equivalent
PHY 5384 Physics of Fiber Optic Systems (3 units)
Physics of electromagnetic waves in fiber-optic systems. Laser modulation, chirp effects, noise. Amplitude, frequency and phase modulation. Optical dispersion (chromatic dispersion, polarization mode dispersion and polarization-dependent losses). Fiber losses and non-linear effects. Optical detectors, receivers, signal to noise ratio, power penalties. Overall system design. This course is equivalent to PHYJ 5308 at Carleton University.

Course Component: Lecture

PHY 5387 Physics of Materials (3 units)
Microscopic characteristics related to the physical properties of materials. Materials families: metals and alloys, ceramics, polymers and plastics, composites, layered materials, ionic solids, molecular solids, etc. Specific materials groups. Equilibrium phase diagrams and their relation to microstructure and kinetics. Experimental methods of characterization. Interactions and reactions. This course is equivalent to PHYJ 5504 at Carleton University.

Course Component: Lecture
Prerequisite: PHY 4382 or equivalent. Cannot be combined for credit with PHY 4387.

PHY 5495 Physics in Modern Technology Work Term
Practical experience for students in the physics in modern technology stream. Graded S (Satisfactory) or NS (Not satisfactory), to be based on the grades obtained for the written and oral reports as well as on the evaluations of the employer. This course is equivalent to PHYS 5905 at Carleton University.

Volet : Stage

PHY 5722 Physique biologique (3 crédits)

Volet : Cours magistral
Exclusion: PHY 4322.

PHY 5740 Physique numérique I (3 crédits)

Volet : Cours magistral

PHY 5741 Physique numérique II (3 crédits)

Volet : Cours magistral

PHY 5742 Simulations numériques en physique (3 crédits)
Un cours ayant pour but d'étudier la physique à l'aide d'un ordinateur dans des situations où les méthodes analytiques sont inappropriées. Solutions numériques des équations de Newton. Dynamique non-linéaire. Simulations de dynamique moléculaire. Simulations Monte-Carlo en physique statistique : modèle d'Ising, percolation, croissance cristalline. Calcul symbolique en physique classique et quantique. Les cours PHY 5742, PHY 5344 ne peuvent être combinés pour l'obtention de crédits. Ce cours est équivalent à PHYJ 5506 à la Carleton University.

Volet : Cours magistral
Prerequisites: PHY 3355 (PHY 3755), PHY 3370 (PHY 3770) and familiarity with FORTRAN, Pascal or C.

PHY 5781 Physique des semi-conducteurs II : Propriétés optiques (3 crédits)

Volet : Cours magistral

PHY 5895 Stage en physique de la technologie moderne
Expérience pratique pour les étudiants dans l'option physique de la technologie moderne. Noté S (satisfaisant) ou NS (non satisfaisant), basée sur l'évaluation de l'employeur et les rapports écrits et oraux décrivant le projet du stage.

Volet : Cours magistral
Préalable : Être accepté dans l'option physique de la technologie moderne du programme de maîtrise et permission du département.

PHY 5922 Advanced Magnetism (3 crédits / 3 units)
Study of some of the experimental and theoretical aspects of magnetic phenomena found in ferro-, feri-, antiferro-magnetic and spin glass materials. Topics of current interest in magnetism. Ce cours est équivalent à PHYJ 5507 à la Carleton University. This course is equivalent to PHYJ 5507 at Carleton University.

Volet / Course Component: Cours magistral / Lecture
Prerequisite: PHY 4385 or equivalent.

PHY 5951 Physique de basses températures / Low Temperature Physics II (3 crédits / 3 units)
Properties of matter at low temperatures. Helium Physics. Thermometry at Low Temperatures. Theory and Technology of Cryogenics Refrigerators. Applied Superconductivity. Recent developments: Cryoelectronic, Quantum Hall Effect. Helium Crystal Growth, Nuclear Magnetic Ordering, Cryogenic Detectors and Polarisated Target for High Energy Physics. Ce cours est équivalent à PHYJ 5409 à la Carleton University. / This course is equivalent to PHYJ 5409 at Carleton University.

Volet / Course Component: Cours magistral / Lecture
Prerequisite: PHY 3355 or PHY 3755

PHY 5966 Experimental Techniques of Nuclear and Elementary Particle Physics (3 crédits / 3 units)
A course intended for students interested in high energy experimental physics. Large accelerators for charged particles. Particle detectors: nuclear emulsion, bubble chamber, spark chamber, Vertex detectors and calorimeters etc. Study of properties of elementary particles through analysis of experimental results. Ce cours est équivalent à PHYJ 5601 à la Carleton University. / This course is equivalent to PHYJ 5601 at Carleton University.

Volet / Course Component: Cours magistral / Lecture
Prerequisite: PHY 4360
PHY 5967 Physique des particules / Elementary Particle Physics (3 crédits / 3 units)
Ce cours est équivalent à PHYS 5602 à la Carleton University. / This course is equivalent to PHYS 5602 at Carleton University.
Volet / Course Component: Cours magistral / Lecture

PHY 6170 Advanced Quantum Mechanics II (3 units)
Systems of identical particles and many-body theory. Lattice and impurity scattering. Quantum processes in a magnetic field. Radiative and non-radiative transitions. Introduction to relativistic quantum mechanics. This course is equivalent to PHYJ 5703 at Carleton University.
Course Component: Lecture
Prerequisite: PHY 5170.

PHY 6371 Topics in Mossbauer Spectroscopy (3 units)
Experimental techniques used to measure Mössbauer spectra. Physics of the Mössbauer effect: recoiless emission/absorption, anisotropic Debye-Waller factors, second order Doppler shifts, etc. Mössbauer lineshape theory with static and dynamic hyperfine interactions. Distributions of static hyperfine parameters. Physics of the hyperfine parameters: origin of the hyperfine field, transferred and supertransferred fields, calculations of electric field gradients, etc. Applications of Mössbauer spectroscopy to various areas of solid state physics and materials science. This course is equivalent to PHYJ 5404 at Carleton University.
Course Component: Lecture
Prerequisite: PHY 5170.

PHY 6382 Physics of Semiconductor Super Lattices (3 units)
Fundamental physics of two-dimensional quantized semiconductor structures. Electronic and optical properties of superlattices and quantum wells. Optical and electronic applications. This course is intended for students registered for the Ph.D. in semiconductor physics research. This course is equivalent to PHYJ 6406 at Carleton University.
Course Component: Lecture
Prerequisite: Advanced undergraduate or graduate course in solid state physics.

PHY 8164 Intermediate Nuclear Physics (3 units)
This course is equivalent to PHYS 5604 at Carleton University.
Course Component: Lecture

PHY 8165 Particle Physics Phenomenology (3 units)
This course is equivalent to PHYS 6601 at Carleton University.
Course Component: Lecture

PHY 8166 Advanced Topics in Particle Physics Phenomenology (3 units)
This course is equivalent to PHYS 6602 at Carleton University.
Course Component: Lecture

PHY 8172 Relativistic Quantum Mechanics (3 units)
This course is equivalent to PHYS 5702 at Carleton University.
Course Component: Lecture

PHY 8173 Quantum Electrodynamics (3 units)
This course is equivalent to PHYS 6701 at Carleton University.
Course Component: Lecture

PHY 8191 Selected Topics in Physics (3 units)
This course is equivalent to PHYS 5901 at Carleton University.
Course Component: Lecture

PHY 8250 Advanced Nuclear Physics (6 units)
Course Component: Lecture

PHY 8290 Selected Topics in Physics (MSc) (6 units)
This course is equivalent to PHYS 5900 at Carleton University.
Course Component: Lecture

PHY 8391 Selected Topics in Physics (PhD) (3 units)
This course is equivalent to PHYS 6901 at Carleton University.
Course Component: Lecture

PHY 8490 Selected Topics in Physics (PhD) (6 crédits)
This course is equivalent to PHYS 6900 at Carleton University.
Volet : Cours magistral

PHY 9998 Examen de synthèse (Doctorat) / Comprehensive Examination (PhD)
Volet / Course Component: Recherche / Research

PHY 9999 PhD Thesis / PhD Thesis
Ce cours est équivalent à PHYS 6909 à la Carleton University. / This course is equivalent to PHYS 6909 at Carleton University.
Volet / Course Component: Recherche / Research