MAÎTRISE EN INGÉNIERIE MATÉRIAUX AVANCÉS ET FABRICATION

En bref

- Grade universitaire offert : Maîtrise en ingénierie (M.Ing.) et Maîtrise en ingénierie (M.Ing.) avec option coop
- Options de statut d'inscription : Temps complet ou temps partiel (ne s'applique pas pour l'option coop)
- Langue d'enseignement : Anglais
- Options d'études (durée prévue du programme) :
  - dans une période de 2 ans à temps complet
- Pour fins d'immigration, le trimestre d'été (mai à août) pour ce programme est considéré un congé prévu au calendrier par l'Université. Les étudiants devront reprendre les études à compter de septembre.
- Unités scolaires : Faculté de génie (https://genie.uottawa.ca/), Institut de génie mécanique et aérospatiale d'Ottawa-Carleton (http://ocimae.ca/) (disponible en anglais seulement).

Description du programme

Programme conjoint Ottawa-Carleton

Fondé en 1983, l'Institut de génie mécanique et aérospatial d'Ottawa-Carleton (IGMAOC) combine les ressources et capacités de recherche des départements de génie mécanique de l'Université d'Ottawa et de génie mécanique et aérospatial de Carleton University.

Principaux domaines de recherche

- l'ingénierie fluidique et thermique
- la mécanique et conception des solides, matériaux avancés et fabrication
- les commandes et la robotique
- le génie biomédical
- le génie spatial et aéronautique

Autres programmes offerts dans la même discipline ou dans une discipline connexe

- Maîtrise ès sciences appliquées Matériaux avancés et fabrication (M.Sc.A.)
- Maîtrise ès sciences appliquées Génie mécanique (M.Sc.A.)
- Maîtrise en ingénierie Génie mécanique (M.Ing.)
- Doctorat en philosophie Matériaux avancés et fabrication (Ph.D.)
- Doctorat en philosophie Génie mécanique (Ph.D.)

Coût et financement

- Frais reliés aux études :

Le montant estimé des droits universitaires (https://www.uottawa.ca/droits-universitaires/) de ce programme est disponible sous la section Financer vos études (http://www.uottawa.ca/etudes-superieures/programmes-admission/financer-etudes/).

Les étudiants internationaux inscrits à un programme d'études en français peuvent bénéficier d'une exonération partielle des droits de scolarité (https://www.uottawa.ca/droits-universitaires/exoneration-partielle-des-droits-de-scolarite/).

- Pour des renseignements sur les moyens de financer vos études supérieures, veuillez consulter la section Bourses et appui financier (https://www.uottawa.ca/etudes-superieures/etudiants/bourses/).

Notes

- Les programmes sont régis par les règlements généraux (http://www.uottawa.ca/etudes-superieures/etudiants/reglements-generaux/) en vigueur pour les études supérieures et par les règlements de l'Institut de génie mécanique et aérospatiale d'Ottawa-Carleton (IGMAOC).
- Conformément au règlement de l'Université d'Ottawa, les étudiants ont le droit de rédiger leurs travaux, leur thèse et de répondre aux questions d'examen en français ou en anglais.

Coordonnées du programme

Bureau des études supérieures, Faculté de génie (https://genie.uottawa.ca/bureau-des-etudes-superieures/)
STE 1024
800 King Edward Ave.
Ottawa ON Canada
K1N 6N5

Tél. : 613-562-5347
Téléc. : 613-562-5129
Courriel : etudesup.genie@uottawa.ca

Twitter | Faculté de génie (https://twitter.com/uottawagenie/)
Facebook | Faculté de génie (https://www.facebook.com/uottawa.engineering/)

Exigences d'admission

Pour connaître les renseignements à jour concernant les dates limites, les tests de langues et autres exigences d'admission, consultez la page des exigences particulières (https://www.uottawa.ca/etudes/etudes-superieures/exigences-admission-particulieres/).

Pour être admissible, vous devez :

- Être titulaire d'un baccalauréat spécialisé ou avec majeure en génie mécanique (ou l'équivalent) avec une moyenne minimale de 70 % (B).

  Note : Les candidats internationaux doivent vérifier les équivalences d'admission (https://www.uottawa.ca/etudes-superieures/international/etudier-uottawa/equivalences-admission/) pour le diplôme obtenu dans leur pays de provenance.

- Identifier au moins un professeur prêt à diriger votre recherche et votre projet (ne s'applique pas à l'option cours seulement).
  - Il est recommandé de communiquer avec le directeur de projet dès que possible.
  - Pour pouvoir vous inscrire, vous devez faire accepter votre candidature par un directeur de projet.
  - Le nom du professeur est requis lors de la demande d'admission.

Exigences linguistiques

Les candidats doivent comprendre et parler couramment la langue d'enseignement, soit le français, soit l'anglais, du programme dans lequel ils veulent s'inscrire. Une preuve de compétence linguistique peut être requise.

Ceux dont la langue maternelle n'est ni le français ni l'anglais doivent fournir une preuve de compétence dans la langue d'enseignement.

Note : Presque toutes les exigences de ces programmes doivent être remplies en anglais. Une très bonne connaissance de la langue anglaise est donc requise.

Note : Les coûts des tests de compétences linguistiques devront être assumés par le candidat.

Notes

- Les installations de recherche sont partagées entre les deux campus. Les étudiants ont accès aux cours, à l'équipement et aux professeurs des deux universités mais ils doivent s'inscrire à l'université d'attache de leur directeur de projet ou de thèse.
- Les activités de recherche peuvent se dérouler soit en anglais, soit en français, soit dans les deux langues selon les compétences linguistiques des professeurs et des membres du groupe de recherche concernés.
- Les conditions d'admission décrites ci-dessus représentent des exigences minimales et ne garantissent pas l'admission au programme.
- L'admission au programme d'études supérieures en matériaux avancés et fabrication est régie par les règlements généraux (http://www.uottawa.ca/etudes-superieures/etudiants/reglements-generaux/) en vigueur pour les études supérieures et par les règlements de l'Institut de génie mécanique et aérospatiale d'Ottawa-Carleton (IGMAOC).

La demande d'admission au régime coop

Vous devez d'abord être admis à l'un des programmes offrant cette option.

Votre demande doit être soumise avant la fin du premier mois d'inscription, soit avant la fin septembre.

L'admission au régime coop se fait sur concours et le processus est géré par le Bureau des programmes d'enseignement coopératif (https://coop.uottawa.ca/fr/). Pour tout renseignement, il faut s'adresser à ce bureau.

Pour être admissible à l'option coop, vous devez :

- être inscrit à temps complet à la maîtrise en ingénierie en matériaux avancés et fabrication (M.Ing.);
- avoir la moyenne pondérée cumulative minimale de l'option coop (7,0 ou 75 %);
- commencer le programme au trimestre d'automne;
- avoir la citoyenneté canadienne, le statut de résident permanent ou d'étudiant étranger (autorisation ou diplomate);
- payer les droits administratifs coop exigés.

Exigences du programme Maîtrise avec option cours et projet

Les exigences de ce programme ont été modifiées. Les exigences antérieures peuvent être consultées dans les annuaires 2020-2021 (http://catalogue.uottawa.ca/fr/archives/).

Les exigences à remplir sont les suivantes :

Cours obligatoire		
GNG 5301	Professional Skills and Responsibility	3 crédits
Cours optionnels		
3 crédits de cours optionnels parmi :		3 crédits
GNG 5120	Technology entrepreneurship for Engineers and Computer Scientists	
GNG 5130	Communication and Influence for Engineers	
GNG 5140	Engineering Design	
9 crédits de cours optionnels en matériaux avancés et fabrication (AMM) de niveau gradué		9 crédits
6 crédits de cours optionnels en matériaux avancés et fabrication (AMM) ou génie mécanique (MCG) de niveau gradué		6 crédits
3 crédits de cours optionnels de niveau gradué		3 crédits
Séminaire		
MCG 5947	Séminaire de maîtrise en ingénierie	
Option cours ou projet		
Une option parmi les suivantes :		
Option 1 :		
AMM 6998	Projet	6 crédits
Option 2 :		
GNG 5902	Projet de stage en entreprise	6 crédits
Option 3 :		
6 crédits de cours optionnels en matériaux avancés et fabrication (AMM), génie général (GNG) ou génie mécanique (MCG) de niveau gradué		6 crédits

Option coop

(Disponible aux étudiants inscrits à l'option avec cours et projet ou à l'option avec cours.)

Afin de maintenir son inscription à l'option coop, les exigences à remplir sont les suivantes :

- être inscrit à temps complet à la maîtrise en ingénierie en matériaux avancés et fabrication;
- maintenir une moyenne pondérée cumulative d'au moins 7,0 (B+ ou 75%);
- obtenir une note de passage (P) pour chaque stage coop : CGI 6001, CGI 6002.

Notes :

- L'option coop offre aux étudiants choisis l'opportunité d'acquérir une expérience de travail pertinente en complétant deux stages de travail rémunérés, chacun d'une durée d'un trimestre.
- Chaque stage est noté P/F (réussite/échec), basé sur le rapport de l'employeur et sur le rapport écrit de l'étudiant. Le rapport de l'étudiant doit comprendre 15-20 pages, incluant les annexes.

- Les crédits reçus pour les stages coop ne peuvent pas être utilisés pour obtenir des équivalences pour d'autres cours. En d'autres mots, les crédits coop sont des crédits supplémentaires aux exigences minimales pour l'obtention du diplôme.

Exigences minimales

La note de passage dans tous les cours est de B.

Passage accéléré de la maîtrise au doctorat

Les étudiants inscrits au programme de maîtrise en matériaux avancés et fabrication à l'Université d'Ottawa ont la possibilité de passer directement au programme de doctorat sans avoir à rédiger la thèse de maîtrise. Pour de plus amples renseignements, veuillez consulter la section « Exigences d'admission » du programme de doctorat.

Recherche
Domaines de recherche et installations

Située au cœur de la capitale du Canada, à quelques pas de la colline du Parlement, l'Université d'Ottawa est l'une des 10 principales universités de recherche au Canada.

uOttawa concentre ses forces et ses efforts dans quatre axes prioritaires de développement de la recherche :

- Le Canada et le monde
- La santé
- La cybersociété
- Les sciences moléculaires et environnementales

Grâce à leurs recherches de pointe, nos étudiants diplômés, nos chercheurs et nos professeurs exercent une forte influence sur les priorités à l'échelle nationale et internationale.

La recherche à la Faculté de génie

Principaux domaines de recherche :

- Génie chimique et biologique
- Génie civil
- Science informatique et génie électrique
- Génie mécanique

Pour d'autres informations, veuillez consulter la liste des membres du corps professoral et leurs domaines de recherche sur **Uniweb**.

IMPORTANT : Les candidats et les étudiants à la recherche de professeurs pour superviser leur thèse ou leur projet de recherche peuvent aussi consulter le site Web de la faculté ou du département (https://www.uottawa.ca/etudes-superieures/etudiants/coordonnees-unites-scolaires/**) du programme de leur choix. La plateforme Uniweb n'est pas représentative de l'ensemble du corps professoral autorisé à diriger des projets de recherche à l'Université d'Ottawa.**

Cours

Les étudiants peuvent, avec l'approbation de leur directeur de recherche ou du comité consultatif, choisir des cours supérieurs offerts dans l'une ou l'autre université. Les cours du programme d'études supérieures sont énumérés ci-dessous. Les descriptions de cours figurent dans les sections relatives aux départements concernés dans les annuaires appropriés. Tous les cours durent un trimestre. Les cours des deux départements sont identifiés par les préfixes suivants :

MCG 5XXX Département de génie mécanique, Université d'Ottawa

MAAJ XXXX Département de génie mécanique et aérospatiale, Carleton University

Tous les cours ne sont pas nécessairement offerts chaque année. Les cours sont offerts dans la langue dans laquelle ils sont décrits.

MCG 5104 Theory of Plates and Shells (3 units)
A general coverage of various approaches to plate problems and the application of these methods to practical cases. A study of the theory of shells including deformation of shells without bending, stresses under various loading conditions, general theory of shells, shells forming surfaces of revolution. This course is equivalent to MAAJ 5004 at Carleton University.
Course Component: Lecture

MCG 5105 Continuum Mechanics (3 units)
Fundamental equations of continuum mechanics. Thermodynamics of continua. Rheological equations. Hamilton's principle for continua. Analytical solution of some elasticity and incompressible fluid dynamic problems. Extension to viscoelasticity and plasticity. Sound waves. Shock waves. Numerical methods of solution. This course is equivalent to MAAJ 5005 at Carleton University.
Course Component: Lecture

MCG 5107 Advanced Dynamics With Applications (3 units)
Review of Euler/Newton and D'Alembert formulation, Euler Angles, gyrodynamics, rotating machinery. Lagrangian dynamics, generalized co-ordinates, virtual work, generalized forces and the power function. Systems constraint forces and equilibrium. Modelling and formulation of multi-degree of freedom vibrational, electro-mechanical, dissipative systems, and other engineering applications. This course is equivalent to MAAJ 5007 at Carleton University.
Course Component: Lecture

MCG 5108 Finite Element Analysis (3 units)
Review of matrix algebra and structural mechanics. Fundamentals of the finite element method. Analysis of two-dimensional trusses and the elastic continuum. Finite element program development, commercial programs, pre and post processers. Isoparametric concept, modelling issues. Steady-state field problems, axisymmetric analysis. Applications in mechanical engineering. This course is equivalent to MAAJ 5008 at Carleton University.
Course Component: Lecture

MCG 5109 Advanced Topics in Finite Element Analysis (3 units)
Finite elements and their solution techniques. Multilayered plate, shell and continua. Eigenvalue and transient analysis, material and geometric non-linearities. Applications to fracture mechanics. Steady and transient state heat conduction. Potential flow. Creeping flow and incompressible viscous flow with inertia. This course is equivalent to MAAJ 5009 at Carleton University.
Course Component: Lecture

MCG 5110 Micromechanics of Solids (3 units)
Introduction. Classes of materials in Micromechanics. Continuum Mechanics vs Probabilistic Micromechanics. Cartesian Tensor Notation. Analysis of stress, strain and motion. The stochastic deformation process and theory. Structured materials and intelligent systems. Experimental approaches. This course is equivalent to MAAJ 5100 at Carleton University.
Course Component: Lecture

MCG 5111 Gas Dynamics (3 units)
Review of thermodynamics. Conservation equations. Wave propagation in compressible media. Isentropic flow. Normal and oblique shock waves. Prandtl-Meyer expansion fans. Applications. Ideal gas flow in ducts of variable section, friction, heat transfer. Method of characteristics. Imperfect gas effects, dissociation, ionization. Methods of measurement. This course is equivalent to MAAJ 5101 at Carleton University.
Course Component: Lecture

MCG 5115 Nonlinear Optimization (3 units)
Formulation of optimization problems. Unconstrained optimization: direct search techniques, gradient techniques. Constrained optimization: by unconstrained minimization, by direct methods. Mathematical programming. Geometric programming. Dynamic programming. Examples and applications in Mechanical Engineering topics. This course is equivalent to MAAJ 5105 at Carleton University.
Course Component: Lecture

MCG 5120 Micro and Nano Systems (3 units)
Fundamental principles governing micro and nano systems, case study of selected applications, and overview of semiconductor micro and nano fabrication techniques. Topics include statics and dynamics at reduced dimensions, electrostatic actuation techniques, nanomechanical resonators, and fundamental performance limits imposed by the equipartition theorem and the fluctuation dissipation theorem.
Course Component: Lecture
The courses MCG 5120, MCG 4137, and MCG 4537 cannot be combined for units.

MCG 5121 Space Mission Analysis and Design (3 units)
Review of solar system and space exploration. Space mission design and geometry. Analysis of orbit design, transfers, interplanetary trajectories. Effect of environment on spacecraft design. Space propulsion and launch vehicle design. Launch sequence, windows, cost. Reusable launch systems. This course is equivalent to MECH 5106 at Carleton University.
Course Component: Lecture

MCG 5122 Smart Structures (3 units)
Structural dynamics principles: modal analysis and wave propagation. Linear time invariant systems: feedback, feedforward, SISO, MIMO, digital and adaptive filters. "Smart" Structures: multifunctional materials, collocation principles, geometric filtering and control authority. Applications in aero-acoustics and aeroelasticity. Courses MCG 5122, MCG 5387 (MECH 5807) cannot be combined for units. This course is equivalent to MECH 5202 at Carleton University.
Course Component: Lecture

MCG 5124 Advanced Kinematics (3 units)
Algebraic-geometry applications: kinematic calibration of serial and in-parallel robots; kinematic synthesis of planar, spherical, spatial mechanisms. Various DH-parametrisations, Jacobian formulations. Topics in projective geometry; Cayley-Klein geometries; Plücker line coordinates; Gröbner bases; Grassmannians; kinematic mapping; Burmester theory. Emphasis on practical applications. This course is equivalent to MECH 5507 at Carleton University.
Course Component: Lecture

MCG 5125 Advanced Dynamics (3 units)
Developing and applying the governing equations of motion for discrete and continuous mechanical systems. Includes Newton-Euler and Lagrangian formulations; classical and finite element approaches for continuous systems; and linear stability, frequency response, and propagation solution methods. This course is equivalent to MECH 5501 at Carleton University.
Course Component: Lecture
Precludes additional credit for MCG 5350 (MECH 5500).

MCG 5131 Heat Transfer by Conduction (3 units)
Steady one-dimensional systems. Equations of Bessel and Legendre. Extended surface. Fourier series and partial differential equations. Steady two-dimensional systems. Steady-state numerical methods. Steady heat source systems. Steady porous systems. Transient systems; stationary and moving sources. Transient numerical method. This course is equivalent to MAAJ 5301 at Carleton University.
Course Component: Lecture

MCG 5132 Heat Transfer by Convection (3 units)
General problems of convection. Fundamental equations. Boundary layer equations. Forced convection in laminar flow. Forced convection in turbulent flow. Free convection. Condensing and boiling. Heat transfer to liquid metals. Heat transfer in high-speed flow. Special topics. This course is equivalent to MAAJ 5302 at Carleton University.
Course Component: Lecture

MCG 5133 Heat Transfer by Radiation (3 units)
Thermal radiation and radiation properties. Radiant interchange among surfaces separated by radiatively non-participating media. Radiant energy transfer through absorbing, emitting and scattering media. Combined conduction and radiation. This course is equivalent to MAAJ 5303 at Carleton University.
Course Component: Lecture

MCG 5134 Heat Transfer With Phase Change (3 units)
Pool boiling. Hydrodynamics of two-phase flow. Flow boiling and flow boiling crisis. Instability of two-phase flow. Condensation. This course is equivalent to MAAJ 5304 at Carleton University.
Course Component: Lecture

MCG 5136 Special Studies in Fluid Mechanics and Heat Transfer (3 units)
This course is equivalent to MAAJ 5306 at Carleton University.
Course Component: Lecture

MCG 5138 Advanced Topics in Mechanical Engineering (3 units)
This course is equivalent to MAAJ 5308 at Carleton University.
Course Component: Lecture

MCG 5141 Statistical Thermodynamics (3 units)
Kinetic theory of an ideal gas. The distribution of molecular velocities. Transport phenomena. Maxwell-Boltzmann statistics. Quantum mechanics. Quantum statistics. Partition functions. Partition functions and thermodynamic properties. Derivations of specific heats of gases. Gas mixtures. Law of mass action. This course is equivalent to MAAJ 5401 at Carleton University.
Course Component: Lecture

MCG 5147 Finite-Volume Methods for Compressible Gas Flows (3 units)
Review of hyperbolic conservation laws and the compressible Euler equations. Godunov-type finite volume schemes. Approximate Riemann solvers. Time-marching methods. Polynomial solution reconstruction. Godunov's theorem. Solution monotonicity. Viscous operators.
Course Component: Lecture

MCG 5148 High-Performance Parallel Scientific Computing (3 units)
Shared- and distributed-memory computer architectures. Parallel speedup, efficiency and Amdahl's law. Classical relaxation methods for linear systems. Domain decomposition methods. Shur-compliment method. Multigrid methods. Krylov subspace methods. Fast Fourier transforms and the Cooley-Tukey algorithm.
Course Component: Lecture

MCG 5149 Non-Equilibrium Gas Dynamics (3 units)
Foundations and applications of compressible fluid flow with non–# equilibrium processes. Includes mechanical, chemical, and thermal non–#equilibrium with application to detonation waves in gases and solids, shock waves with chemical and vibrational relaxation and impulsive motion in arbitrary media.
Course Component: Lecture

MCG 5151 Laminar Flow Theory (3 units)
Derivation and exact solutions of the Navier-Stokes equations. Low Reynolds number flows, Stokes flow. Oseen flow, lubrication theory. Laminar boundary layers. Introduction to hydrodynamic stability. This course is equivalent to MAAJ 5501 at Carleton University.
Course Component: Lecture

MCG 5152 Theory of Turbulence (3 units)
Review of the basic theories and experimental results of turbulent flow. Universal equilibrium theory, locally isotropic theories, isotropic turbulence, homogeneous shear flow, turbulent pipe and channel flow, jets, wakes, boundary layers. Turbulent diffusion of passive contaminants. Modelling of turbulence. This course is equivalent to MAAJ 5502 at Carleton University.
Course Component: Lecture

MCG 5155 Inviscid Flow Theory (3 units)
Langrangian and Eulerian description of fluid motion. Euler equations, velocity potential, irrotational flow, stream function, singular flows. Conformal mapping, Schwarz-Christoffel theorems. Airfoil theory, circulation and lift. This course is equivalent to MAAJ 5505 at Carleton University.
Course Component: Lecture

MCG 5156 Measurement in Fluid Mechanics (3 units)
Review of the common experimental techniques used in fluid mechanical research and applications. Flow visualization techniques. Hot-wire anemometry. Laser-Doppler anemometry. Measurement of concentration, temperature, force, pressure. This course is equivalent to MAAJ 5506 at Carleton University.
Course Component: Lecture

MCG 5157 Numerical Computation of Fluid Dynamics and Heat Transfer (3 units)
Governing equations. Explicit, implicit, finite difference and control volume procedures for approximating the parabolic and elliptic sets of partial differential equations and boundary conditions. Numerical solution by direct and iterative Gauss-Seidel relaxation methods. Considerations of stability, convergence, and numerical diffusion. Computational problems. This course is equivalent to MAAJ 5507 at Carleton University.
Course Component: Lecture

MCG 5167 Nuclear Reactor Engineering (3 units)
Course Component: Lecture

MCG 5169 Advanced Topics in Reliability Engineering (3 units)
Overview of classical reliability concepts. Fault tree construction and evaluation. Common-cause failure analysis of engineering systems. Human reliability modelling in engineering systems. Human unreliability data banks. Reliability of information and communication systems. This course is equivalent to MAAJ 5609 at Carleton University.
Course Component: Lecture

MCG 5170 Computer-Aided Design (3 units)
The design process. Structure of computer-aided drafting software. Analysis and optimization software. Software integration. Parametric design. Major group design project which integrates concepts from all major areas of mechanical engineering. Courses MCG 5170, MCG 4322 cannot be combined for units. This course is equivalent to MAAJ 5700 at Carleton University.
Course Component: Lecture
Exclusion: May not be taken for credit with MCG 4322.

MCG 5171 Applied Reliability Theory (3 units)
Failure rate. Repair time. System reliability estimation: binomial model. Strength stress model. Failure detection and isolation. Statistical quality control. This course is equivalent to MAAJ 5701 at Carleton University.
Course Component: Lecture

MCG 5173 Systems Engineering and Integration (3 units)
Introduction to modelling methods employed for the planning and design of sub-systems and complex systems. Discrete and continuous time, lumped and distributed parameters models. State estimation. Parameters identification. Discretization and stochastic effects. Technological systems modelling and simulation examples. This course is equivalent to MAAJ 5703 at Carleton University.
Course Component: Lecture

MCG 5177 Robot Mechanics (3 units)
Robotics overview. Transformations. Basics of robot kinematics, statics and dynamics. Introduction to practical robots, control and programming. Project in analysis, design or application of manipulators. Courses MCG 5177, MCG 4132 cannot be combined for units. This course is equivalent to MAAJ 5707 at Carleton University.
Course Component: Lecture

MCG 5184 Mechatronics (3 units)
Models for passive and active components for electro-mechanical systems. Network representation of signals and energy transmission and conversion. Selection of sensors and actuators for the control of mechanical systems. Modelling and simulation for the design of mixed dynamic systems. Courses MCG 5184, MCG 4136 cannot be combined for units. This course is equivalent to MAAJ 5804 at Carleton University.
Course Component: Tutorial, Lecture

MCG 5185 Multivariable Digital Control (3 units)
Quantization. Z-Transform. State equations. Jordan canonical form. Multirate and nonsynchronous samplings. Controllability and observability of digital systems. Digital controllers design using bilinear transformation. Digital PID controller. Stability. Optimal control of digital systems. Examples of controlling mechanical system actuators. This course is equivalent to MAAJ 5805 at Carleton University.
Course Component: Lecture

MCG 5186 Non-Linear Discontinuous Dynamics and Control (3 units)
Hamiltonian dynamics. Hamiltonian control systems. Lyapunov dynamics. Decoupling. Phase space analysis. Switching and sliding mode control. Boundary layer continuous approximation. Actuator, sensors and controller requirements. Manipulation control examples. This course is equivalent to MAAJ 5806 at Carleton University.
Course Component: Lecture

MCG 5191 Combustion in Premixed Systems (3 units)
Stoichiometry, thermo-chemistry, ignition, flame propagation, flame stabilization, diffusion flames, turbulent combustion, modelling. This course is equivalent to MAAJ 5901 at Carleton University.
Course Component: Lecture

MCG 5192 Combustion in Diffusion Systems (3 units)
Gaseous jet flames, combustion of liquid droplets, atomization, spray flames, coal combustion, fluidized bed combustion. This course is equivalent to MAAJ 5902 at Carleton University.
Course Component: Lecture

MCG 5300 Fundamentals of Fluid Dynamics (3 units)
Differential equations of motion. Viscous and inviscid regions. Potential flow: superposition; thin airfoils; finite wings; compressibility corrections. Viscous flow: thin shear layer approximation; laminar layers; transition; turbulence modelling. Convective heat transfer: free versus forced convection; energy and energy integral equations; turbulent diffusion. This course is equivalent to MECH 5000 at Carleton University.
Course Component: Lecture

MCG 5301 Theory of Viscous Flows (3 units)
Navier-Stokes and boundary layer equations; mean flow equations for turbulent kinetic energy; integral formulations. Stability, transition, turbulence, Reynolds stresses; separation. Calculation methods, closure schemes. Compressibility, heat transfer, and three-dimensional effects. This course is equivalent to MECH 5001 at Carleton University.
Course Component: Lecture

MCG 5303 Incompressible Non-Viscous Flows (3 units)
The fundamental equations and theorems for non-viscous fluid flow; solution of two-dimensional and axisymmetric potential flows; low-speed airfoil and cascade theory; wing lifting-line theory; panel methods. This course is equivalent to MECH 5003 at Carleton University.
Course Component: Lecture

MCG 5304 Compressible Non-Viscous Flows (3 units)
Steady isentropic, frictional, and diabatic flow; shock waves; irrotational compressible flow, small perturbation theory and similarity rules; second-order theory and unsteady, one-dimensional flow. This course is equivalent to MECH 5004 at Carleton University.
Course Component: Lecture

MCG 5306 Theory of Subsonic Flows (3 units)
Course Component: Lecture

MCG 5307 Theory of Supersonic Flows (3 units)
Course Component: Lecture

MCG 5308 Experimental Methods in Fluid Mechanics (3 units)
Fundamentals of techniques of simulation of fluid dynamic phenomena. Theoretical basis, principles of design, performance and instrumentation of ground test facilities. Applications to aerodynamic testing. This course is equivalent to MECH 5008 at Carleton University.
Course Component: Lecture

MCG 5309 Environmental Fluid Mechanics Relating to Energy Utilization (3 units)
Characteristics of energy sources and emissions into the environment. The atmosphere; stratification and stability, equations of motion, simple winds, mean flow, turbulence structure and dispersion near the ground. Flow and dispersion in groundwater, rivers, lakes and oceans. Physical and analytical modelling of environmental flows. This course is equivalent to MECH 5009 at Carleton University.
Course Component: Lecture

MCG 5310 Performance and Economics of V/Stol Aircraft (3 units)
Aircraft performance analysis with emphasis on factors affecting take-off, landing and economic performance; high lift schemes; operating economics. This course is equivalent to MECH 5100 at Carleton University.
Course Component: Lecture

MCG 5311 Dynamics and Aerodynamics of Low Speed Flight (3 units)
Static stability theory. Euler's equations for rigid body motion; the linearized equations of motion; stability derivatives and their estimation. Longitudinal and lateral dynamic response of an aircraft to control and disturbance. This course is equivalent to MECH 5101 at Carleton University.
Course Component: Lecture

MCG 5314 Ground Transportation Systems and Vehicles (3 units)
Performance characteristics, handling and directional stability, ride comfort and safety of various types of ground vehicle systems including road vehicles, terrain-vehicle systems, guided transport systems, and advanced ground transport technology. This course is equivalent to MECH 5104 at Carleton University.
Course Component: Lecture

MCG 5315 Orbital Mechanics and Space Craft Control (3 units)
Orbital dynamics and perturbations due to the Earth's figure, the sun, and the moon with emphasis on mission planning and analysis. Rigid body dynamics applied to transfer orbit and on-orbit momentum management and control of spacecraft. Effects of flexible structures on a spacecraft control system. This course is equivalent to MECH 5105 at Carleton University.
Course Component: Lecture

MCG 5321 Methods of Energy Conversion (3 units)
Technical, economic and environmental aspects of present and proposed large-scale systems of energy conversion. This course is equivalent to MECH 5106/MECH 5201 at Carleton University.
Course Component: Lecture

MCG 5322 Nuclear Engineering (3 units)
Reactor design and safety requirement overview; reactor physics, chemistry and engineering, CANDU reactor design and operation; CANDU reactor fuel channels, thermalhydraulics and fuel; reactor safety design and analysis; IAEA and Canadian safety analysis requirements; reactor accidents; nuclear energy policy.
Course Component: Lecture

MCG 5324 Building Performance Simulation (3 units)
During this course students will develop an understanding of the methodologies and theory employed historically and contemporarily in the Building Performance Simulation (BPS) field, develop capabilities for extending the functionality of BPS tools, and establish skills in applying BPS tools in research, analysis, and design. Includes: Experiential Learning Activity
Course Component: Lecture

MCG 5325 Wind Engineering (3 units)
Theoretical and practical areas pertinent to the operation of wind turbines. World energy needs, wind farms versus traditional power plants, global wind characteristics, efficient turbine design, electrical components, modes of turbine operation and control, mechanical design, economic and environmental concerns. This is equivalent to MECH5206 at Carleton.
Course Component: Lecture

MCG 5326 System Modelling, Dynamics and Control (3 units)
The course provides an understanding of system modelling and the connection between energy domains. Within the temporal and/or frequency domains, system identification techniques and control aspects are explored for discrete and continuous systems along with lumped and distributed parameter models. This is equivalent to MECH5508 at Carleton
Course Component: Lecture

MCG 5327 Nonlinear Systems Analysis & Controls (3 units)
Introduction to nonlinear systems, stability of periodic solutions and limit cycles. Second-order nonlinear systems. Mathematical foundations for stability analysis, Lyapunov and LaSalle's methods. Autonomous and non-autonomous systems. Input-Output stability formalisms. Basics of nonlinear control techniques based on Lyapunov methods. This is equivalent to MECH5509 at Carleton.
Course Component: Lecture

MCG 5328 3D Machine Vision: From Robots to the Space Station (3 units)
Through lectures and project work, this course introduces fundamental 3D machine vision methods (triangulation and time-of-flight), presents cutting-edge neural network approaches, and explores major engineering applications (e.g. robotics, autonomous vehicles, space navigation) where perception of the 3D environment is essential. This is equivalent to MECH5103 at Carleton.
Course Component: Lecture

MCG 5329 Space Robotics (3 units)
This graduate course in space robotics is designed to teach the full spectrum of manipulator robotics applied to in-orbit servicing and repair of spacecraft and the removal of orbital debris as the first step towards developing a space infrastructure. The course covers space manipulator missions, kinematics, dynamics, trajectory generation, control systems and some special topics. This course is equivalent to MECH 5108 at Carleton University.
Course Component: Lecture

MCG 5330 Engineering Acoustics (3 units)
Review of acoustic waves in compressible fluids; acoustic pressure, intensity and impedance; physical interpretation and measurement; transmission through media; layers, in-homogeneous media, solids; acoustic systems; rooms, ducts, resonators, mufflers, properties of transducers; microphones, loudspeakers, computational acoustics. This course is equivalent to MECH 5300 at Carleton University.
Course Component: Lecture

MCG 5331 Aero-Acoustics (3 units)
The convected wave equation; theory of subsonic and supersonic jet noise; propeller and helicopter noise; fan and compressor noise; boundary layer noise, interior noise; propagation in the atmosphere; sonic boom; impact on environment. This course is equivalent to MECH 5301 at Carleton University.
Course Component: Lecture

MCG 5332 Instrumentation Techniques (3 units)
An introduction for the non-specialists to the concepts of digital and analog electronics with emphasis on data acquisition, processing and analysis. Topics covered include operational amplifiers, signal processing, digital logic systems, computer interfacing, noise in electronic systems. Hands-on sessions illustrate theory and practice. This course is equivalent to MECH 5302 at Carleton University.
Course Component: Lecture

MCG 5334 Computational Fluid Dynamics of Compressible Flows (3 units)
Solution techniques for parabolic, elliptic and hyperbolic equations developed for problems of interest to fluid dynamics with appropriate stability considerations. A staged approach to solution of full Euler and Navier-Stokes equations is used. Grid generation techniques appropriate for compressible flows are introduced. This course is equivalent to MECH 5304 at Carleton University.
Course Component: Lecture

MCG 5341 Turbomachinery (3 units)
Types of machines. Similarity: performance parameters; characteristics; cavitation. Velocity triangles. Euler equation: impulse and reaction. Radial pumps and compressors: analysis, design and operation. Axial pumps and compressors: cascade and blade-element methods; staging; off-design performance; stall and surge. Axial turbines. Current design practice. Courses MCG 5341, MCG 4110 (MECH 4305) cannot be combined for units. This course is equivalent to MECH 5401 at Carleton University.
Course Component: Lecture

MCG 5342 Gas Turbines (3 units)
Interrelationship among thermodynamic, aerodynamic, and mechanical design. Ideal and real cycle calculations. Cycle optimization; turbo-shaft, turbojet, turbofan. Component performance. Off-design performance; matching of compressor, turbine, nozzle. Twin-spool matching. This course is equivalent to MECH 5402 at Carleton University.
Course Component: Lecture

MCG 5343 Advanced Thermodynamics (3 units)
The course covers three major topics: review of fundamentals from a consistent viewpoint, properties and equations of state, and applications and special topics. The third topic includes an introduction to statistical thermodynamics. This course is equivalent to MECH 5403 at Carleton University.
Course Component: Lecture

MCG 5344 Gas Turbine Combustion (3 units)
This course covers two major topics: combustion fundamentals and gas turbine combustor design. Combustion fundamentals include fuel evaporation, chemistry of combustion, chemical kinetics and emission formation and introduction to computational combustion modeling. Combustor design addresses the interrelationship between operational requirements and combustion fundamentals. Courses MCG 5344, MCG 5480 (MECH 5800) cannot be combined for units if MCG 5344 is taken as the topic. This course is equivalent to MECH 5400 at Carleton University.
Course Component: Lecture

MCG 5347 Conductive and Radioactive Heat Transfer (3 units)
Analytical, numerical and analog solutions to steady-state and transient conduction heat transfer in multi-dimensional systems. Radiative heat exchange between black, grey, non-grey diffusive and specular surfaces, including effects of athermanous media. This course is equivalent to MECH 5407 at Carleton University.
Course Component: Lecture

MCG 5348 Convective Heat and Mass Transfer (3 units)
Analogies between heat, mass and momentum transfer. Forced and free convection relations for laminar and turbulent flows analytically developed where possible and otherwise deduced from experimental results, for simple shapes and in heat exchangers. Mass transfer theory and applications. This course is equivalent to MECH 5408 at Carleton University.
Course Component: Lecture

MCG 5349 Two-Phase Flow and Heat Transfer (3 units)
Course Component: Lecture

MCG 5350 Advanced Vibration Analysis (3 units)
General theory of discrete multi-degree-of-freedom vibrating systems. Emphasis on numerical techniques of solving complex vibrating systems, with selected applications from aeronautical, civil, and mechanical engineering. This course is equivalent to MECH 5500 at Carleton University.
Course Component: Lecture

MCG 5352 Optimal Control Systems (3 units)
Review of transfer function and state-space system descriptions. Elements of the optimal control problem. Variational calculus. Optimal state feedback control. Riccati equations. Optimal observers and Kalman-Bucy Filters. Extension to discrete time systems including an introduction to dynamic programing. Practical applications are emphasized throughout the course. This course is equivalent to MECH 5502 at Carleton University.
Course Component: Lecture

MCG 5353 Robotics (3 units)
The history of and introduction to robotics methodology. Robots and manipulators; homogeneous transformation, kinematic equations, solving kinematic equations, differential relationships, motion trajectories, dynamics. Control; feedback control, compliance, servomotors, actuators, external and internal sensors, grippers and vision systems. Microprocessors and their application to robot control. Programming. This course is equivalent to MECH 5503 at Carleton University.
Course Component: Lecture

MCG 5354 Guidance, Navigation and Control (3 units)
Guidance system classification, flight control systems, targeting, target tracking, sensing. Modern multivariable control analysis; design requirements, sensitivity, robustness, perturbations, performance analysis. Modern filtering and estimation techniques. Terrestrial navigation; tactical air navigation (TACAN), star trackers Guidance mission and performance. Aircraft, missile and spacecraft guidance and control. This course is equivalent to MECH 5504 at Carleton University.
Course Component: Lecture

MCG 5355 Stability Theory and Applications (3 units)
Fundamental concepts and characteristics of modern stability definitions. Sensitivity and variational equations; linear variational equations; phase space analysis; Lyapunov's direct method. Autonomous and nonautonomous systems; stability in first approximation; the effect of force type on stability; frequency method. This course is equivalent to MECH 5505 at Carleton University.
Course Component: Lecture

MCG 5356 Neuro and Fuzzy Control (3 units)
Knowledge-based controllers. Fuzzy control: mathematics, relations, operations, approximate reasoning. Fuzzy knowledge base control and structure. Fuzzification, inference engine; defuzzification. Nonlinear, adaptive fuzzy control systems. Stability, Neuro-Control: processing, learning. Adaptation of artificial neural systems: associative memories, algorithms, applications, and network implementation. Neurofuzzy systems: industrial applications. Courses MCG 5356, ELG 5386 (EACJ 5386), ELG 5196 (EACJ 5709) cannot be combined for units. This course is equivalent to MECH 5506 at Carleton University.
Course Component: Lecture
Exclusion: ELG 5386

MCG 5361 Creative Problem Solving and Design (3 units)
Problem-solving processes and how they can be applied in engineering design. Emphasis on learning methodologies rather than accumulating information. Techniques can be successfully applied in any engineering speciality. This course is equivalent to MECH 5601/IDES 5301 at Carleton University.
Course Component: Lecture

MCG 5365 Finite Element Analysis I (3 units)
An introduction to the finite element methodology, with emphasis on applications to heat transfer, fluid flow and stress analysis. The basic concepts of Galerkin's method, interpolation, numerical integration, and isoparametric elements are taught using simple examples. This course is equivalent to MECH 5605 at Carleton University.
Course Component: Lecture

MCG 5366 Finite Element Analysis II (3 units)
Time marching heat flow problems with linear and nonlinear analysis. Static plasticity. Time-dependent deformation problems; viscoplasticity, viscoelasticity, and dynamic analysis. Isoparametric elements and numerical integration are used throughout. This course is equivalent to MECH 5606 at Carleton University.
Course Component: Lecture

MCG 5367 The Boundary Element Method (Bem) (3 units)
Integral equations. The BEM for potential theory and for elastostatics in two-dimensions. Boundary elements and numerical integration schemes. Practical applications. This course is equivalent to MECH 5607 at Carleton University.
Course Component: Lecture

MCG 5370 Special Topics in Mechanical and Aeronautical Engineering (3 units)
Course Component: Lecture

MCG 5375 CAD/CAM (3 units)
Computer-aided design process, computer graphics including hardware and software standards. Wire frames, boundary representations, constructive solids geometry, sculptured surfaces. Data bases. Graphics and product interchange files. Computer-aided manufacturing; numerical control, CNC, DNC, adaptive control. CAM programming, popular commercial CAD programs. Management issues. This course is equivalent to MECH 5705 at Carleton University.
Course Component: Lecture

MCG 5376 Special Topics in Mechanical and Aerospace Engineering (3 units)
Topic will vary from year to year.
Course Component: Lecture

MCG 5380 Safety and Risk Assessment of Nuclear Power (3 units)
Course Component: Lecture

MCG 5384 Special Topics in Mechanical and Aerospace Engineering (3 units)
Topic will vary from year to year.
Course Component: Lecture

MCG 5396 Directed Studies (3 units)
Course Component: Research
Permission of the Department is required.

MCG 5398 Independent Engineering Study (3 units)
Students pursuing a master's degree by course work carry out an independent study, analysis, and solution of an engineering problem or design project. The results are given in the form of a written report and presented at a departmental seminar. Carried out under the general direction of a faculty member. This course is equivalent to MECH 5908 at Carleton University.
Course Component: Lecture

MCG 5470 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5471 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5472 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5473 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5474 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5475 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5476 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5477 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5478 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5479 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5480 Special Topics in Mechanical and Aerospace Engineering (3 units)
In-depth study of a topic in Mechanical and Aerospace Engineering. This course is equivalent to MECH 5800 at Carleton University.
Course Component: Lecture

MCG 5481 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5482 Special Topics in Mechanical and Aerospace Engineering (3 units)
This course is equivalent to MECH 5805 at Carleton University.
Course Component: Lecture

MCG 5483 Fundamentals of Combustion (3 units)
Emphasis on gas phase reacting flows. Background of combustion thermodynamics, diffusion mass transfer, and chemical kinetics. Detonations and deflagrations. Chemical and dynamic structure of flames. Gaseous flame propagation under laminar and turbulent conditions. Flame stabilization and extinction. Introduction to burning rate theory.
Course Component: Lecture

MCG 5484 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5485 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5486 Special Topics an Mechanical and Aerospace Engineering (3 units)
This course is equivalent to MECH 5806 at Carleton University.
Course Component: Lecture

MCG 5487 Special Topics in Mechanical and Aerospace Engineering (3 units)
This course is equivalent to MECH 5807 at Carleton University.
Course Component: Lecture

MCG 5488 Special Topics in Mechanical and Aerospace Engineering (3 units)
This course is equivalent to MECH 5803 at Carleton University.
Course Component: Lecture

MCG 5489 Special Topics in Mechanical and Aerospace Engineering (3 units)
Topics will vary from year to year. This course is equivalent to MECH 5801 at Carleton University.
Course Component: Lecture

MCG 5490 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5491 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5492 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5493 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5494 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5495 Special Topics in Mechanical and Aerospace Engineering (3 units)
Course Component: Lecture

MCG 5551 Théorie d'écoulement visqueux (3 crédits)
Dérivation des solutions exactes des équations de Navier-Stokes. Écoulement à petit nombre de Reynolds. Écoulement de Stokes. Écoulement d'Oseen. Théorie de lubrification. Couches limites laminaires. Introduction à la stabilité hydrodynamique. Ce cours est équivalent à MAAJ 5408 à la Carleton University.
Volet : Cours magistral

MCG 5552 Théorie de turbulence (3 crédits)
Révision des théories fondamentales et des résultats expérimentaux des écoulements turbulents. Théorie universelle de l'équilibre, théorie isotropique locale. Turbulence isotropique, contrainte homogène des écoulements, écoulements turbulents dans les tuyaux et les canaux, jets, sillages, couches limites. Diffusion turbulente. Modèles de turbulence. Ce cours est équivalent à MAAJ 5409 à la Carleton University.
Volet : Cours magistral

MCG 5557 Méthodes numériques en mécanique (3 crédits)
Équations primitives. Méthodes de différences finies. Méthodes intégrales. Critère de stabilité. Calcul des écoulements transitoires laminaires tri-dimensionnels. Méthodes MAC de Los Alamos. Calcul des écoulements multidimensionnels turbulents. Modèles de turbulence. Méthode numérique de Gosman. Ce cours est équivalent à MAAJ 5500 à la Carleton University.
Volet : Cours magistral

MCG 5900 Séminaire de M.A.Sc. / MASc Seminar
Une série de séminaires présentés par des étudiants aux cycles supérieurs et des chercheurs invités. En plus d'avoir à présenter un séminaire, les étudiants doivent assister et participer à au moins dix séminaires. Noté S (satisfaisant) ou NS (non satisfaisant). / A series of seminars presented by graduate students and invited researchers. Students are required to attend and participate in at least 10 seminars and to make one presentation. Graded S (Satisfactory) / NS (Not satisfactory).
Volet / Course Component: Séminaire / Seminar

MCG 5947 Séminaire de maîtrise en ingénierie / Master of Engineering Seminar
Une série de séminaires présentés par des étudiants aux cycles supérieurs et des chercheurs invités. Les étudiants doivent assister et participer à au moins dix séminaires. Noté S (satisfaisant) ou NS (non satisfaisant). / A series of seminars presented by graduate students and invited researchers. Students are required to attend and participate in at least 10 seminars. Graded S (Satisfactory) / NS (Not satisfactory).
Volet / Course Component: Séminaire / Seminar

MCG 6998 Projet / Project (6 crédits / 6 units)
Projet en génie mécanique ou en matériaux avancés et fabrication dirigé par un professeur approuvé par le directeur des études supérieures et donnant lieu à la rédaction d'un rapport approfondi (30-40 pages approx). Noté S (satisfaisant) ou NS (non satisfaisant) par le directeur du projet et un autre professeur nommé par le directeur des études supérieures en génie mécanique. Le projet est normalement complété en une session d'études à temps plein. / Project in mechanical engineering or in advanced materials and manufacturing supervised by a professor approved by the director of graduate studies and leading to the writing of an in-depth report (approx. 30-40 pages). Graded S (Satisfactory) or NS (Not satisfactory) by the supervisor and by another professor appointed by the director of graduate studies in Mechanical Engineering. The project can normally be completed in one session of full-time study.
Volet / Course Component: Recherche / Research
Permission of the Department is required.

MCG 9900 Séminaire de doctorat / PhD Seminar
Une série de séminaires présentés par des étudiants aux cycles supérieurs et des chercheurs invités. En plus d'avoir à présenter un séminaire, les étudiants doivent assister et participer à au moins 15 séminaires. Noté S (satisfaisant) ou NS (non satisfaisant) / A series of seminars presented by graduate students and invited researchers. Students are required to attend and participate in at least 15 seminars and make one presentation. Graded S (Satisfactory) / NS (Not satisfactory).
Volet / Course Component: Séminaire / Seminar

MCG 9997 Préparation du rapport de candidature au doctorat / Preparation of Ph.D. Candidacy Paper
À la suite de la réussite à l'examen de synthèse, inscription requise de tous les candidats au doctorat jusqu'à ce que le projet de thèse soit accepté par le Comité consultatif. / Following completion of the comprehensive examination, registration required for all PhD candidates until the thesis proposal is accepted by the Advisory Committee.
Volet / Course Component: Recherche / Research

MCG 9998 Examen général du doctorat / PhD Comprehensive
Inscription requise de tous les candidats au doctorat jusqu'à la réussite à l'examen de synthèse. / Registration required for all PhD candidates until the comprehensive examination is passed.
Volet / Course Component: Recherche / Research