DOCTORATE IN PHILOSOPHY
ADVANCED MATERIALS AND
MANUFACTURING

Summary
• Degree offered: Doctorate in Philosophy (PhD)
• Registration status option: Full-time
• Language of instruction: English
• Program option (expected duration of the program):
  • within four years
• Academic units: Faculty of Engineering (http://engineering.uottawa.ca/), Ottawa-Carleton Institute for Mechanical and Aerospace Engineering (http://ocimae.ca/)

Program Description
Ottawa-Carleton Joint Program

Established in 1983, the Ottawa-Carleton Institute for Mechanical and Aerospace Engineering (OCIMAE) combines the research strengths of the Department of Mechanical Engineering at the University of Ottawa and the Department of Mechanical and Aerospace Engineering at Carleton University.

Research activities can be conducted either in English, French or both, depending on the language used by the professor and the members of his or her research group.

Research facilities are shared between the two campuses. Students have access to the professors, courses and facilities at both universities.

Main Areas of Research
• Thermal and fluid engineering
• Solid mechanics and design
• Materials and manufacturing
• Controls and robotics
• Biomedical engineering
• Aeronautical and space engineering

Other Programs Offered Within the Same Discipline or in a Related Area
• Master of Engineering Advanced Materials and Manufacturing (MASc)
• Master of Engineering Advanced Materials and Manufacturing (MEng)
• Master of Applied Science in Mechanical Engineering (MASc)
• Master of Engineering in Mechanical Engineering (MEng)
• Doctorate in Philosophy Mechanical Engineering (PhD)

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 and by the general regulations of the Ottawa-Carleton Institute for Mechanical and Aerospace Engineering (OCIMAE).
• 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 Engineering (https://engineering.uottawa.ca/graduate-studies-office/)
STE 1024
800 King Edward Ave.
Ottawa ON Canada
K1N 6N5
Tel.: 613-562-5347
Fax.: 613-562-5129
Email: engineering.grad@uottawa.ca

Twitter | Faculty of Engineering (https://twitter.com/uOttawaGenie/?lang=en)
Facebook | Faculty of Engineering (https://www.facebook.com/uottawa.engineering/)

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 (https://www.uottawa.ca/graduate-studies/programs-admission/apply/specific-requirements/) webpage.

To be eligible, candidates must:
• Hold a master’s degree* in mechanical or aerospace engineering (or the equivalent) with a minimum average of B+.

*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.

• 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 enroll, 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 be able to understand and fluently speak English or French proficiently. Proof of linguistic proficiency may be required.

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

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

Notes
- The choice of research supervisor will determine the primary campus location of the student. It will also determine which university awards the degree.
- 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 and by the general regulations of the Ottawa-Carleton Institute for Mechanical and Aerospace Engineering (OCIMAE).

Fast-Track from Master’s to PhD
Students enrolled in the master’s program in advanced materials and manufacturing at the University of Ottawa may be eligible to fast-track directly into the doctoral program without writing a master’s thesis, provided they successfully complete 27 course units for the PhD.

Program Requirements
Doctorate
Students must meet the following requirements:

Compulsory Courses:
- 6 optional course units in advanced materials and manufacturing (AMM) at the graduate level
- 3 optional course units in mechanical engineering (MCG) or advanced materials and manufacturing (AMM) at the graduate level

Seminar:
- MCG 9900 PhD Seminar

Thesis Proposal:
- AMM 9997 Preparation of Ph.D. Candidacy Paper

Comprehensive Examination:
- AMM 9998 PhD Comprehensive

Thesis:
- THD 9999 Doctoral Thesis

Note(s)
1. The optional course units must be approved by the Department.
2. Students are responsible for ensuring they have met all of the thesis requirements (http://www.uottawa.ca/graduate-studies/students/theses/). The thesis must be based on original research carried out under the direct supervision of a faculty member of the Department.

Minimum Requirements
The passing grade in all courses is B.

Students who fail 6 units, or whose research progress is deemed unsatisfactory will be withdrawn from the program.

Research
Research Fields & Facilities
Located in the heart of Canada’s capital, a few steps away from Parliament Hill, the University of Ottawa is among Canada’s top 10 research universities.

uOttawa focuses research strengths and efforts in four Strategic Areas of Development in Research (SADRs):
- Canada and the World
- Health
- e-Society
- Molecular and Environmental Sciences

With cutting-edge research, our graduate students, researchers and educators strongly influence national and international priorities.

Research at the Faculty of Engineering
Areas of research:
- Chemical and Biological Engineering
- Civil Engineering
- Electrical Engineering and Computer Science
- Mechanical Engineering

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
In all programs, the student may choose graduate courses from either university with the approval of the Advisor or Advisory Committee. The available graduate courses are listed below. Course descriptions are to be found in the departmental section of the calendar concerned. All courses are of one session duration. Courses of each department are indicated by the prefix of the first number given as follows:

MCG 5XXXX Department of Mechanical Engineering, University of Ottawa

MAAJ XXXX Department of Mechanical and Aerospace Engineering, Carleton University

Not all of the listed courses are given each year. The course is offered in the language in which it is described.
AMM 5101 Theory of Elasticity (3 units)
Course Component: Lecture

AMM 5102 Advanced Stress Analysis (3 units)
Course Component: Lecture

AMM 5103 Theory of Perfectly Plastic Solids (3 units)
Course Component: Lecture

AMM 5106 Advanced Topics in Elasticity (3 units)
Course Component: Lecture

AMM 5117 Introduction to Composite Materials (3 units)
Course Component: Lecture

The courses AMM 5117, MCG 5117, MCG 4144, and MCG 4544 cannot be combined for units.

AMM 5118 Introduction to Plasticity (3 units)
Course Component: Lecture

AMM 5119 Fracture Mechanics (3 units)
Course Component: Lecture

AMM 5121 Materials Selection in Engineering Design (3 units)
Course Component: Lecture

AMM 5122 Failure analysis of high-temperature protective coatings for aerospace applications (3 units)
Investigation of failure mechanisms and mechanics of high-temperature protective coatings. Examples are given for thermal barrier coatings, oxidation resistance coatings. The detail mechanics involves coating adhesion, bond strength, interfacial fracture toughness, buckling, delamination, spallation and life prediction.
Course Component: Lecture

AMM 5123 Microstructure and Properties of Materials (3 units)
Essential microstructural features of metals and alloys: crystal structure, dislocations, grain boundaries. The importance of these features in controlling mechanical properties is emphasized. Analytical techniques for observing microstructure in metals and other materials: TEM, SEM, electron diffraction, spectrometry.
Course Component: Lecture

AMM 5124 Fatigue and Damage Tolerance in Aircraft (3 units)
Fatigue and crack propagation problems applied to specific aircraft structures, airworthiness, Load Spectra and Stress Histories, Effects of Cracks and Notches, Fatigue, Linear Elastic Fracture Mechanics, Crack propagation Analysis.
Course Component: Lecture

AMM 5125 Materials characterization techniques (3 units)
Materials characterization techniques, methodologies of materials characterization: crystal structure, microstructural morphology, and Chemical microanalysis. The main methods of characterization include: (1) X-ray and electron diffractions; (2) optical, scanning and transmission electron microscopy, (3) X-ray and electron spectroscopy. The microanalytical techniques include both qualitative and quantitative methods. Technical aspects of preparing samples and operating instruments are also introduced in order to help students acquire basic knowledge on practical aspects.
Course Component: Lecture

AMM 5126 Deformation of Materials (3 units)
The deformation and fracture properties of metals, ceramics and polymers. Introduction to dislocation theory. Rheological models. Analysis and interpretation of constant strain rate, constant stress and stress relaxation tests in terms of the material structure.
Course Component: Lecture

AMM 5129 Hot Working Metals (3 units)
High temperature mechanical properties in metals. Types of recovery, recrystallization and precipitation in metals and their effects on hot strength and structure. Hot rolling of metals. Selection of rolling schedules. Influence of as-rolled structures on room temperature tensile and fracture stresses, impact strength.
Course Component: Lecture

AMM 5130 Deformation and Fracture of Engineering Materials (3 units)
This course will cover both macroscopic (continuum) and microscopic (discrete) aspects of deformation and fracture in engineering materials. Topics covered include elasticity, plasticity, dislocation theory, strengthening mechanisms, cracks and notches, crack tip stress fields and plastic zones, energy principles, ductile, brittle and fatigue fracture, and toughening mechanisms.
Course Component: Lecture

The courses AMM 5130, MCG 5130, MCG 4135, and MCG 4535 cannot be combined for units.

AMM 5137 Special Studies in Solid Mechanics and Materials (3 units)
Course Component: Lecture

AMM 5138 Advanced Topics in Advanced Materials and Manufacturing (3 units)
Course Component: Lecture

AMM 5144 Superalloys and Ceramix-Metal Matrix Composites (3 units)
Manufacture and properties of superalloys and ceramic-metal matrix composites used in aerospace, turbine, mining and energy applications. Powder metallurgy, phase diagrams, mechanical alloying, deformation, creep, fatigue, fracture mechanics, wear and corrosion. Physics-based modelling of materials' strength including the contribution of solid solution, precipitation and ceramic particle strengthening as a function of application temperature.
Course Component: Lecture

AMM 5159 Advanced Production Planning and Control (3 units)
The principles of production management. Methods engineering, manufacturing control. Recording and evaluation of operations. Financial and production planning. Inventory control. Automation. Factory planning. This course is equivalent to MAAJ 5509 at Carleton University.
Course Component: Lecture

AMM 5168 Industrial Organization (3 units)
Course Component: Lecture

AMM 5179 Manufacturing System Analysis (3 units)
Course Component: Lecture

AMM 5182 Theory of Elastic Instability (3 units)
Course Component: Lecture

AMM 5317 Experimental Stress Analysis (3 units)
Course Component: Lecture

AMM 5345 Surfaces and Coatings (3 units)
Surface Engineering: Coatings & Thin Films Technologies. SURFACE ENGINEERING is a multidisciplinary activity intended to tailor the properties of the surfaces of engineering components so that their function and serviceability can be improved. Different surface modification, thin films and thick coating manufacturing methods such as surface hardening, chemical conversion coating, electro deposition, electroless plating, thermal spraying, physical vapour deposition, and chemical vapour deposition, are introduced.
Course Component: Lecture

AMM 5362 Failure Prevention (3 units)
Design of engineering structures to ensure against failure due to fatigue or brittle fracture. Nature of fatigue and brittle fracture; selection of suitable material, geometry, and inspection procedures for the load and environmental conditions. This course is equivalent to MECH 5602 at Carleton University.
Course Component: Lecture

AMM 5364 Computational Metallurgy (3 units)
Development of microstructure in alloys in solidification processes and post-solidification processing. Nucleation and growth of solid phase. Formation of a dendrite structure, macro and micro segregations. Pore formation in castings. Thermodynamic and kinetics of phase transformations and structure evolution in solid alloys. This course is equivalent to MECH 5604 at Carleton University.
Course Component: Lecture

AMM 5369 Metallic Phases and Transformations (3 units)
Thermodynamics of crystals, phase diagrams, principles of alloy phases, thermal analysis. Transformation rate and mechanisms. Short and long range diffusional transformations; diffusionless transformations. Phase transformations in engineering systems.
Course Component: Lecture

AMM 5374 Integrated Manufacturing – CIMS (3 units)
Topics essential to CIMS including computer graphics, geometric modelling, numerically controlled machining, and flexible manufacturing. The fundamental data structures and procedures for computerization of engineering design, analysis and production. This course is equivalent to MECH 5704 at Carleton University.
Course Component: Lecture

AMM 5381 Lightweight Structures (3 units)
Course Component: Lecture

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

AMM 6998 Projet / Project (6 crédits / 6 units)
Projet en génie 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 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

Volet / Course Component: Recherche / Research

AMM 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 consultation. / 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

AMM 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

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)

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 processors. 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)

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)

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)

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)

Course Component: Lecture

MCG 5147 Finite-Volume Methods for Compressible Gas Flows (3 units)

Course Component: Lecture

MCG 5148 High-Performance Parallel Scientific Computing (3 units)

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)
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 5305 Uninhabited Aircraft Systems Design (3 units)
Theory of flight and air vehicle performance; propulsion systems; launch and recovery. Regulatory development; privacy policies. Mission design; sensor performance. Guidance, navigation, control and communications theory. System-level reliability; life cycle cost assessment. Includes: Experiential Learning Activity. This course is equivalent to MECH 5005 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
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)

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 Nonlinear Systems Analysis & Controls (3 units)

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 Nonlinear Systems Analysis & Controls (3 units)

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 programming. 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)
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)
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)
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 in 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 5511 Théorie d’écoulement visqueux (3 crédits)
Dévolution 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)
Volet : Cours magistral

MCG 5557 Méthodes numériques en mécanique (3 crédits)
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