Department of Mechanical and Aerospace Engineering

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The Department

Chair of the Department:
Robert Bell
Associate Chair (Graduate Studies):
E.G. Plett

The Department of Mechanical and Aerospace Engineering offers programs of study and research leading to M.Eng. degrees in Aerospace Engineering, Materials Engineering, and Mechanical Engineering, and to Ph.D. degrees in Aerospace and Mechanical Engineering. These degrees are offered through the Ottawa-Carleton Institute for Mechanical and Aerospace Engineering, which is jointly administered by the Department of Mechanical and Aerospace Engineering at Carleton University, and the Department of Mechanical Engineering at the University of Ottawa. For further information, including admission and program requirements, see page 151.

Programs of research and study are offered in several areas:

- Aerodynamics and Gas Dynamics
- Heat Transfer
- Stress and Failure Analysis
- Lightweight Structures and Aeroelasticity
- Vibration Analysis
- Computer-Aided Design and Engineering
- Robotics
- Vehicle (Performance and Safety)
- Engineering
- Nuclear Engineering
- Energy Systems
- Energy Conversion and Utilization
- Manufacturing Engineering
- Materials Engineering

The Department has a major research commitment, both analytical and experimental, to thermofluid-dynamic and mechanical problems of gas turbine engine design and operation. Current work includes flow prediction and analysis in turbo-machines; two- and three-dimensional boundary layer behaviour; tip-leakage effects and other losses; dynamics of gas turbine power plants; design and performance of highly loaded turbines; engine noise; stress, deformation, and vibration of compressor and turbine blades and discs; finite element analysis; dynamics of high-speed rotors; failure modes of materials in extreme environments.

Another area of intense research effort in the Department is computer-aided engineering. Activities in this field include computer-aided analysis (including computational fluid dynamics as well as the finite and boundary element methods), computer-aided design and computer-integrated manufacturing. Projects include thermal and mechanical analysis of welding and casting processes, heat and fluid flow analyses, stress, deformation (manufacturing processes), vibration and fracture mechanics studies and solids modelling. Computer-aided engineering is well supported by computer hardware and software, including a state-of-the-art network of engineering workstations. The Department has a substantial involvement in the Manufacturing Research Centre of Ontario.

As part of the faculty interest in transportation, the Department is active in research on air and ground vehicle technology. Current studies include computational methods for steady and unsteady flows over complex configurations; effects of roughness on aerodynamic performance; aircraft noise; boundary layer separation and control; propeller and rotor aerodynamics and noise. The Transport Technology Research Laboratory has been organized for ground transport studies; design and optimization of off-road vehicles; vehicle safety; anti-lock braking systems; vehicle-terrain interaction; effect of vibration on vehicle performance; dynamics of air-cushion and magnetically levitated vehicles; composite and structural elements.

Members of the Department are engaged in research on various aspects of energy conversion, storage and utilization. In addition to the previously mentioned work on gas turbines, research is being undertaken on nuclear energy, effectiveness of energy end-use, and behaviour in wind of energy-conserving cladding systems for buildings. In the nuclear energy field, research is being undertaken in heat transfer and fluid flow aspects of CANDU and SLOWPOKE reactors, with a major effort on thermohydraulic problems in reactor safety. Work is also in progress on reactor safety in general, with a special emphasis on risk. Research activities in this field also include studies on the utilization of CANDU reactors for thermal energy supply as well as electrical generation and on applications of up-rated SLOWPOKE reactors to low-temperature industrial heating and to building energy needs.

Another area of interest is in design, manufacturing and materials technology; in particular, there are programs on the properties of welded joints, heat treatment and forming studies.

The departmental laboratories are well equipped for the various research activities described above, and these are supported by a machine shop, electronics shop and extensive computing facilities mentioned earlier.

The extensive laboratory facilities of the National Research Council, and of the Department of Energy, Mines and Resources are also used, by special arrangement, for research and graduate studies of mutual interest. Strong contacts are maintained with the gas turbine, aircraft and nuclear power industries.

Graduate Courses*

Only a selection of the courses listed below is given in a particular academic year.

- Engineering 88.500F1(MCG5300)
Fundamentals of Fluid Dynamics
Differential equations of fluid motion. Subsonic flow; potential flow theory; outline of panel methods and flows over wings and bodies. Supersonic flow; oblique shock waves and Prandtl-Meyer expansions, flows over wings and bodies. Viscous flow: the boundary-layer approximation; outline of boundary-layer calculation methods; coupling of viscous and inviscid regions of flow.
Also offered at the undergraduate level, with different requirements, as 87.432, for which additional credit is precluded.
S.A. Sjolander.

- Engineering 88.501W1(MCG5301)
Theory of Viscous Flows
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.
R.J. Kind.

- Engineering 88.503F1(MCG5303)
Incompressible Non-Viscous Flow
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.
Miroslav Mokry.

- Engineering 88.504F1(MCG5304)
Compressible Non-Viscous Flow
Steady isentropic, frictional, and diabatic flow; shock waves; irrotational compressible flow, small perturbation theory and similarity rules; second-order theory, unsteady, one-dimensional flow.
W. Carscallen.

- Engineering 88.508W1(MCG5308)
Experimental Methods in Fluid Mechanics
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 (subsonic to hypersonic speeds); wind effects on structures; air and water pollution.
W.G. Richarz.

- Engineering 88.509W1(MCG5309)
Environmental Fluid Mechanics Relating to Energy Utilization
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.
R.J. Kind.

- Engineering 88.510W1(MCG5310)
Performance and Economics of Aircraft
Aircraft performance analysis with emphasis on factors affecting take-off, landing and economic performance; high lift schemes; operating economics.
Not offered 1994-95.

- Engineering 88.511F1(MCG5311)
Dynamics and Aerodynamics of Flight
Brief review of 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.
S. Baillie.

- Engineering 88.514F1(MCG5314)
Ground Transportation Systems and Vehicles
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.
References: Wong, J.Y., *Theory of Ground Vehicles, Terramechanics and Off-Road Vehicles*.
J.Y. Wong.

***** F,W,S indicates term of offering. Courses offered in the fall *and* winter will be followed by T.
The number following the letter indicates the credit weight of the course: 1 denotes a half-course credit, 2 denotes a full-course credit, etc.

- Engineering 88.517W1(MCG5317)
Experimental Stress Analysis
Introduction to theory of elasticity. Photo-elasticity: types of polariscopes, two- and three-dimensional stress fields, frozen patterns. Photoelastic coatings. Strain gauges; gauge factors, sensitivity, calibration, and temperature compensation. Moire fringes, brittle lacquers, mechanical strain gauges.
Robert Bell.

- Engineering 88.521W1(MCG5321)
Methods of Energy Conversion
Technical, economic and environmental aspects of present and proposed large-scale systems of energy conversion.
J.T. Rogers.

- Engineering 88.522W1(MCG5380)
Safety and Risk Assessment of Nuclear Power
Safety aspects of nuclear power reactors, particularly the CANDU reactor. Principles of nuclear power safety. Probabilistic safety assessment. Analysis of severe accidents. Nuclear power risks in perspective with risks of other electrical energy systems.
J.T. Rogers.

- Engineering 88.530F1(MCG5330)
Engineering Acoustics
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.
W.G. Richarz.

- Engineering 88.531W1(MCG5331)
Aeroacoustics
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.
W.G. Richarz.

- Engineering 88.532F1(MCG5332)
Instrumentation Techniques
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.
W.G. Richarz.

- Engineering 88.534W1(MCG5334)
Computational Fluid Dynamics of Compressible Flows
Following a review of the classification of partial differential equations as applied to fluid dynamics, some finite difference formulation techniques are used to develop the appropriate difference equations. Solution techniques for parabolic, elliptic and hyperbolic equations are reviewed and several approaches are applied to examine the relative merits of each for the problems of interest, with stability considered as appropriate. The full complexity of the Euler and Navier Stokes Equations is approached in stages. Grid generation techniques are introduced and the compressible flow of fluids in and around bodies is solved by several different numerical approaches.
E.G. Plett.

- Engineering 88.541F1(MCG5341)
Turbomachinery
This course deals with the generalized performance of turbomachinery, and with the thermo- and aerodynamic design of axial and radial flow machines. The emphasis is on compressible flow machines. Also offered at the undergraduate level, with different requirements, as 88.435, for which additional credit is precluded.
M.I. Yaras.

- Engineering 88.542W1(MCG5342)
Gas Turbines
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.
H.I.H. Saravanamuttoo.

- Engineering 88.543W1(MCG5343)
Advanced Thermodynamics
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.
E.G. Plett.

- Engineering 88.547W1(MCG5347)
Conductive and Radiative Heat Transfer
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.
E.G. Plett.

• Engineering 88.548W1(MCG5348)
Convective Heat and Mass Transfer
Review of analogies between heat, mass and momentum transfer. Free and forced convection from theoretical and experimental viewpoint for laminar and turbulent flows in ducts and over flat plates and blunt bodies. Heat transfer-friction relationship in heat exchangers. Film and dropwise condensation. Boiling with forced and natural convection. Two-phase flow. Mass transfer in stationary, laminar and turbulent flow systems.
E.G. Plett.

• Engineering 88.549F1(MCG5349)
Two-Phase Flow and Heat Transfer
Topics covered include basic equations of liquid-vapour and liquid-gas flows including choked flows and flow oscillations, heat transfer rates and critical heat fluxes. Applications to practical problems are emphasized.
J.T. Rogers.

• Engineering 88.550W1(MCG5350)
Advanced Vibration Analysis
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.
James Kirkhope.

• Engineering 88.552W1(MCG5352)
Optimal Control Systems
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.
K.R. Goheen.

• Engineering 88.553F1(MCG5353)
Robotics
The history and an 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. Programing.
J.Z. Sasiadek.

• Engineering 88.561W1(MCG5361)
Creative Problem Solving and Design
This course outlines problem-solving processes and how they can be applied in engineering design. The student will be introduced to and be expected to practice various systematic and creative problem-solving techniques. The emphasis is on the student's learning methodologies rather than accumulating information. The techniques may be successfully applied in any engineering speciality.
(Also offered as Industrial Design 85.531)
Geza Kardos.

• Engineering 88.562F1(MCG5362)
Failure Prevention (Fracture Mechanics and Fatigue)
The course deals with the design of engineering structures to ensure against failure due to fatigue or brittle fracture. It emphasizes an understanding of the nature of fatigue and brittle fracture, and thereby the selection of suitable material, geometry, and inspection procedures for the load and environmental condition intended.
Robert Bell.

• Engineering 88.563W1(MCG5381)
Lightweight Structures
Structural behaviour. Stresses and shear flows in single stroke multicell structures. Bending, twisting of thin-walled beams. Bending of plates. Thin membrane shell structures. Energy principles. Air supported structures. Matrix methods and modal analysis in lightweight structures.
P.V. Straznicky.

• Engineering 88.565F1(MCG5365)
Finite Element Analysis I
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.
J.A. Goldak.

• Engineering 88.566W1(MCG5366)
Finite Element Analysis II
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.
J.A. Goldak.

• Engineering 88.567F1(MCG5367)
The Boundary Integral Equation (BIE) Method
Introduction to integral equation. Potential theory: Dirichlet and Neumann problems in engineering practice. Two-dimensional BIE for harmonic problems.

Constant line elements. Numerical treatment of BIE. Two-dimensional BIE for elastostatics. Isoparametric line elements. Numerical treatment of BIE and integration schemes. Use of BIE computer programs for solving problems in elastostatics and potential theory.
C.L. Tan.

- Engineering 88.568F1(MCG5368)
Advanced Engineering Materials
This course presents an overview of the mechanical properties of engineering material as a basis for materials selection and design in computer-integrated manufacturing. The first part of the course considers the phenomenological aspects of strength, fracture, fatigue and corosion/wear, test methods, material properties and use of data-bases. The second part covers the structure and deformation/fracture mechanism of the engineering materials: metals and alloys, ceramics, polymers, rapidly-solidified alloys, surface-modified materials, cellular solids, composite materials. Precludes additional credit for Engineering 88.468.
Prerequisite: Engineering 88.270 or 88.271.

- Engineering 88.570F1, W1
Special Topics in Mechanical and Aerospace Engineering
Courses in special topics related to mechanical engineering and aerospace engineering, not covered by other graduate courses; course details will be available prior to registration.

Topics for 1994-95

- Stability Theory and Applications
Fundamental concepts and common characteristics of modern stability definitions. Sensitivity and variational equations; linear variational equations; phase space; the direct method of Lyapunov; mathematical approximation methods. Application of the theory to stability problems; central force motion, vibrations, control systems, elastodynamics, aircraft, rockets and satellites.
F.F. Afagh.

- Computational Metallurgy
The course will follow the development of microstructure in liquids from solidification through precipitation, grain growth, phase transformations and fracture. The focus will be on computational methods capable of modelling or simulating the evolution of microstructure.
J.A. Goldak.

- Advanced Space Studies
This course in advanced space studies is intended to introduce the student to space technology, space physics and space life sciences as it relates to manned spaceflight and utilization of the space environment. The course content is based upon that covered by astronauts during their first year of basic training. The subject areas to be covered may include the following: overview of spacecraft design, technical requirements for manned spaceflight, space shuttle systems, space biology and life sciences, fluid physics in microgravity, remote sensing from space, aeronomy, and the mobile servicing system.
Parvez Kumar.

- Guidance, Navigation and Control
Guidance system classification, flight control systems, targeting, target tracking and sensing. Modern multivariable control analysis; design requirements, sensitivity, robustness, perturbations, linearization, qualitative comparison, performance analysis. Modern filtering and estimation techniques, Kalman filter, nonlinear filtering, extending Kalman filter, Kalman filter design and performance, prediction and smoothing. Terrestial navigation; common requirements and design external navigation systems, global positioning systems (GPS), tactical air navigation (TACAN), long-range navigation (LORAN), star trackers. Guidance mission and performance. Navigation and guidance filtering design. Advanced guidance systems. Aircraft, missile and spacecraft guidance and control. Spacecraft altitude and control.
J.Z. Sasiadek.

- Orbital Mechanics and Spacecraft Control
Orbital dynamics and perturbations due to the Earth's figure, the sun and the moon will be studied with emphasis on mission planning and analysis. Rigid body dynamics will be developed and applied to transfer orbit and on-orbit momentum management and control of spacecraft and the effect of flexible structures on a spacecraft control system will be studied.
D.A. Staley.

- Microgravity or Low Gravity Science
This course will examine in detail the transport phenomena that are important in microgravity environments. Topics include capillary effects, transport by diffusion and wetting and absorption phenomena. Comparisons will be made between analytical and ground test results and experiments from space missions.
M.Z. Saghir.

- Continuum Mechanics with Application to Plasticity
This course is intended to provide an introduction to continuum mechanics, primarily from a solid mechanics viewpoint, and elementary plasticity theory. Topics will include: tensors, indicial notation

and tensor manipulation. Continuum descriptions of deformation, strain and stress. Objective tensors. Constitutive relations, elasticity and elementary plasticity. Concept of yield surface, flow potential and normality. Material rate sensitivity. Stress wave propagation.
M.J. Worswick.

- Discrete Time Control Systems

This course covers analysis and synthesis of digital systems and controllers, emphasizing both theory and practical aspects of system analysis and controller design. Topics include relationship between continuous and discrete systems, reachability and related concepts, pulse response and convolution, Z-Transform theory, system sampling, computer control, control system design in state space and frequency domain, stability, implementation issues.
G.S. Vukovich.

- Engineering 88.574W1(MCG5374)

Computer-Integrated Manufacturing Systems (CIMS)
This course presents an overview of the topics essential to CIMS. These include computer graphics, geometric modelling, kinematic analysis, numerically controlled machining, robotics, and flexible manufacturing systems, with the objective of understanding the fundamental data structures and procedures that are appropriate to the computerization of engineering design, analysis and production.
Also offered at the undergraduate level, with different requirements, as 88.474, for which additional credit is precluded.
J.A. Goldak.

- Engineering 88.575F1(MCG5375)

CAD/CAM
Fundamentals of computer-aided design (CAD); review of the design process, elements of computer graphics including hardware and software standards. Wire frames, boundary representations, constructive solids geometry, sculptured surfaces. Data bases. Graphics and product interchange files. Fundamentals of computer-aided manufacturing (CAM): numerical control (NC), CNC, DNC, adaptive control. CAM programming, introduction to popular commercial CAD programs. Management issues including acquisition, training and security.
Also offered at the undergraduate level, with different requirements, as 88.475, for which additional credit is precluded.
Text: Hearn and Baker, *Computer Graphics*
K.R. Goheen.

- Engineering 88.596F1, W1, S1(MCG5395)

Directed Studies

- Engineering 88.598F3, W3, S3(MCG5398)

Independent Engineering Study
In this course, the student pursuing a master's degree by course work will carry out an independent study, analysis, and solution of an engineering problem or design project. The results will be given in the form of a written report and may be presented at a departmental seminar. The study will be carried out under the general direction of a faculty member.

- Engineering 88.599F4, W4, S4

M.Eng. Thesis

- Engineering 88.699F, W, S

Ph.D. Thesis

Other Courses of Particular Interest

Civil and Environmental Engineering

82.511	Introductory Elasticity
82.512	Advanced Elasticity
82.513	Finite Element Methods in Stress Analysis
82.524	Behaviour and Design of Steel Structures
82.534	Intercity Transportation, Planning and Management

Systems and Computer Engineering

94.501	Simulation and Modelling
94.504	Mathematical Programing for Engineering Applications
94.505	Optimization Theory and Methods
94.541	Adaptive Control
94.542	Advanced Dynamics with Applications to Robotics
94.552	Advanced Linear Systems
94.553	Stochastic Processes

Physics

75.447	Statistical Physics
75.511	Classical Mechanics and Theory of Fields

Mathematics and Statistics

70.486	Numerical Analysis
70.586	Numerical Analysis