

# Civil Engineering (CIVE)

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## **CIVE 5101 [0.5 credit] (CVG 7120)**

### **Solid Mechanics**

Cartesian tensor notation; stresses and strains in a continuum; transformations, invariants; equations of motion; constitutive relations; generalized Hooke's Law, bounds for elastic constant: strain energy, superposition, uniqueness; formulation of plane stress and plane strain problems; energy principles, variational methods; plasticity.

## **CIVE 5102 [0.5 credit] (CVG 7121)**

### **Advanced Elasticity**

Continuation of topics introduced in CIVE 5101. Complex variable solutions: torsional and thermal stresses; axially symmetric three-dimensional problems, Love's strain potential, Boussinesq-Galerkin stress functions; problems related to infinite and semi-infinite domains. Introduction to numerical methods of stress analysis, comparison of solutions.

Prerequisite(s): CIVE 5101 or permission of the Department.

## **CIVE 5103 [0.5 credit] (CVG 7122)**

### **Finite Element Analysis 1**

Advanced finite element methods for linear systems. The relationship with variational and Galerkin formulations, system of linear equations, polynomial interpolation, numerical integration, and theory of elasticity is explored. Isoparametric formulations for structural and continuum elements are examined. Introduction to linear dynamics and nonlinear problems.

## **CIVE 5104 [0.5 credit] (CVG 7123)**

### **Earthquake Engineering and Analysis**

Advanced vibration analysis techniques; Rayleigh-Ritz procedure; subspace iteration; derived Ritz coordinates; proportional and non-proportional damping; introduction to seismology; earthquake response analysis via time and frequency domain; response spectrum approach; multiple input excitations; design considerations and code requirements; other advanced topics in earthquake engineering.

Prerequisite(s): CIVE 5106 or permission of the Department.

## **CIVE 5105 [0.5 credit] (CVG 7124)**

### **Finite Element Analysis 2**

Variational and Galerkin formulations: assumed displacement, assumed stress and hybrid elements; plate bending: convergence, completeness and conformity, patch test, Kirchhoff and Mindlin plate theories, nonlinear elasticity and plasticity; geometric non-linearity, Eulerian and Lagrangian formulations; incremental and iterative schemes, finite elements in dynamics.

Prerequisite(s): CIVE 5103 or permission of the Department.

## **CIVE 5106 [0.5 credit] (CVG 7137)**

### **Dynamics of Structures**

Structural dynamics, single and multi-degree-of-freedom systems, formulation of equations of motion, methods of analytical mechanics, free and forced vibrations, normal mode analysis, numerical methods for the response analyses of single and multiple-degree-of-freedom systems.

## **CIVE 5107 [0.5 credit] (CVG 5321)**

### **Finite Elements in Field Problems**

Use of Galerkin and Ritz finite element formulation to solve one and two dimensional field problems. Steady state and time-dependent phenomena involving potentials, heat transfer, fluid flow, diffusion, and dispersion with emphasis on practical applications. Basic knowledge of third year-level undergraduate engineering mathematics and physics required.

Also listed as ENVE 5402.

## **CIVE 5108 [0.5 credit]**

### **Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures**

Design and construction of nonlinear structural models. Accounting for mass, material behaviour, damping, and nonlinear geometry. Use of pushover and time history analysis methods. Design and modelling of structural systems using passive damping devices and isolation systems.

## **CIVE 5200 [0.5 credit] (CVG 7138)**

### **Masonry Behaviour and Design**

Properties of masonry materials and assemblages. Behaviour and design of walls, columns and lintels. Treatment of specialized design and construction topics. Design of lowrise and highrise structures. Discussion of masonry problems. Emphasis on a practice-oriented approach.

Also offered at the undergraduate level, with different requirements, as CIVE 4403, for which additional credit is precluded.

## **CIVE 5203 [0.5 credit] (CVG 7125)**

### **Theory of Structural Stability**

Elastic and inelastic behaviour of beam-columns; elastic and inelastic buckling of frames; application of energy methods to buckling problems; lateral-torsional buckling of columns and beams; buckling of plates; local buckling of columns and beams.

Prerequisite(s): CIVE 5205 or equivalent.

## **CIVE 5204 [0.5 credit] (CVG 7126)**

### **Advanced Steel Structures**

Limit states design philosophy; material behaviour; tension members; plate buckling; torsion; lateral torsional buckling; beams, axially loaded columns and beam-column behaviour; brittle fracture and fatigue; frame stability and second order effects.

**CIVE 5205 [0.5 credit] (CVG 7127)****Advanced Structural Analysis**

Matrix structural analysis; force and displacement method of analysis for planar and space structures; symmetric and anti-symmetric structures; analysis of nonlinear structures: geometric and material nonlinearities; large displacement theory and iteration strategy.

**CIVE 5206 [0.5 credit] (CVG 7128)****Prestressed Concrete**

Behaviour and analysis of prestressed concrete elements subjected to axial loads, flexure and shear: material properties; prestressing systems; linear and non-linear behaviour; deflections; compression-field approaches; disturbed regions; restraint of deformations; design requirements; applications to pressure vessels, bridges and frames.

**CIVE 5208 [0.5 credit] (CVG 7130)****Advanced Reinforced Concrete**

The research background, development, and limitations in current building code provisions for reinforced concrete; yield line theory of slabs; safety and limit state design; computer design of concrete structures.

**CIVE 5209 [0.5 credit] (CVG 7100)****Geotechnical Case Studies**

The critical study of case histories relating to current procedures of design and construction in geotechnical engineering. The importance of instrumentation and monitoring field behaviour will be stressed. In-situ testing.

**CIVE 5300 [0.5 credit] (CVG 7101)****Advanced Soil Mechanics**

Effective stress, pore pressure parameters, saturated and partially saturated soils; seepage; permeability tensor, solutions of the Laplace equation; elastic equilibrium; anisotropy, non-homogeneity, consolidation theories; shear strength of cohesive and cohesionless soils; failure and yield criteria.

**CIVE 5303 [0.5 credit] (CVG 7103)****Pavements and Materials**

An analysis of the interaction of materials, traffic, and climate in the planning, design construction, evaluation, maintenance, and rehabilitation of highway and airport pavements.

**CIVE 5304 [0.5 credit] (CVG 7150)****Intercity Transportation**

Current modal and intermodal issues, including energy. Framework and process of intercity transport planning and management. Recent trends and system development. Passenger and freight demand and service characteristics. Future prospects and possibilities.

**CIVE 5305 [0.5 credit] (CVG 7151)****Traffic Engineering**

Introduction to principles of traffic engineering. Basic characteristics of drivers, vehicles, and traffic. Volume, speed, and delay studies. Traffic stream characteristics and queuing theory. Capacity analysis of roads and intersections. Safety.

**CIVE 5306 [0.5 credit] (CVG 7152)****Highway Materials**

Materials characterization and strength evaluation of soils, stabilized soils, aggregates, and asphalt concrete. Effects of low temperatures and frost on materials behaviour.

**CIVE 5307 [0.5 credit] (CVG 7153)****Urban Transportation**

Urban transportation systems, planning and management. Urban development models, an introduction. Urban transportation policy.

**CIVE 5308 [0.5 credit] (CVG 7154)****Highway Geometric Design**

Principles of highway geometric design. Components of the highway system, their interrelationships, abilities, limitations, and their relations with the design elements. Safety and human factors, and their interaction with the highway elements. New and evolving concepts.

**CIVE 5309 [0.5 credit] (CVG 7155)****Transportation Supply**

Advanced treatment of transportation planning and management concepts and techniques: transport supply issues, capacity and costs, evaluation of system improvements and extensions, transportation and development, policy impact analysis.

**CIVE 5401 [0.5 credit] (CVG 7156)****Transportation Economics**

Transportation, economic analysis framework. Transport industry output. Carrier operations. Issue of resource utilization, measurement, economics, supply of infrastructure, pricing; subsidies, externalities. Transport policy in Canada.

**CIVE 5402 [0.5 credit] (CVG 7159)****Transportation Terminals**

Framework for passenger terminal planning and design. Theory: the transfer function and network modeling; pedestrian flow characteristics; capacity of corridors, stairs, escalators, and elevators; layout planning. Practical applications: air, rail, metro, bus, ferry, and multi-modal terminals.

**CIVE 5403 [0.5 credit] (CVG 7158)****Airport Planning**

Framework for airport planning and design. Aircraft characteristics; demand forecasting; airport site selection; noise, airside capacity; geometric design; the passenger terminal complex; cargo area; general aviation; ground transportation; land use planning.

**CIVE 5404 [0.5 credit]****Introduction to Infrastructure Management**

Infrastructure management and its relationship to facility and asset management; challenges facing infrastructure managers; tools for effective IM; concept of total quality management; economic analysis of maintenance, rehabilitation and reconstruction; use of life cycle cost analysis in decision making, development and use of IM systems.

**CIVE 5500 [0.5 credit] (CVG 7104)****Earth Retaining Structures**

Approaches to the theoretical and semi-empirical analysis of earth retaining structures. Review of the earth pressure theories. Analysis and design methods for rigid and flexible retaining walls, braced excavations, and tunnels. Instrumentation and performance studies.

**CIVE 5501 [0.5 credit] (CVG 7105)****Advanced Foundation Engineering**

Review of methods of estimating compression and shear strength of soils. Bearing capacity of shallow and deep foundations. Foundations in slopes. Pile groups. Use of in-situ testing for design purposes.

**CIVE 5502 [0.5 credit] (CVG 7106)****In-Situ Geotechnique**

Subsurface exploration program. Soil and rock sampling. Geo-physical methods. Mechanical and hydraulic properties of soil and rock. Determination of strength and deformability. Critical evaluation of vane, pressuremeter, screw plate, dilatometer, borehole shear and plate load tests. Pumping, recharge and packer tests. In-situ stress measurements.

**CIVE 5503 [0.5 credit] (CVG 7107)****Numerical Methods in Geomechanics**

Advanced theories of soil and rock behaviour. Plasticity models. Generalized failure criteria. Critical state and cap models. Dilatancy effects. Associative and non-associative flow rules. Hardening rules. Consolidation, visco-elasticity, creep behaviour. Finite element formulation. Iterative schemes. Time marching schemes. Solution of typical boundary value problems.

Prerequisite(s): CIVE 5101, CIVE 5103, or permission of the Department.

**CIVE 5504 [0.5 credit]****Seepage Through Soils**

Surface-subsurface water relations. Steady flow. Flownet techniques. Numerical techniques. Seepage analogy models. Anisotropic and layered soils. Water retaining structures. Safety against erosion and piping. Filter design. Steady and non-steady flow towards wells. Multiple well systems. Subsidence due to ground water pumping.

Precludes additional credit for ENVE 5301.

**CIVE 5505 [0.5 credit] (CVG 7109)****Geotechnical Earthquake Engineering**

Seismic hazards, earthquakes and ground motion, wave propagation, ground response analysis, soil properties for dynamic analysis: laboratory tests, in-situ tests, modulus and damping curves, liquefaction susceptibility, post liquefaction response, seismic effects on slope stability, retaining structures.

Precludes additional credit for CIVE 5801 (2001-2003).

**CIVE 5507 [0.5 credit]****Blast Load Effects on Structures**

Threats, risk analysis, vulnerability assessment; explosives: types and mechanisms; load determination; response of structural elements under blast loads, analysis and design for blast loads; blast mitigation, retrofit of structures; post-event assessment.

Also listed as IPIS 5507.

**CIVE 5600 [0.5 credit] (CVG 7131)****Project Management**

Managing building development, design, and construction including interrelationships among owners, developers, financing sources, designers, contractors, and users; project manager role and tasks; project objectives; feasibility analyses; budgets and financing; government regulations; environmental and social constraints; cost, time, and content quality controls and processes; human factors.

**CIVE 5601 [0.5 credit] (CVG 7140)****Engineering, Statistics, and Probabilities**

Review of basic concepts in statistics and probabilities. Bayes' Theorem. Distributions. Parameter estimation. Goodness-of-fit. Regression and correlation. OC curves. Monte Carlo simulation. ANOVA. Probability-based design criteria. System reliability. Selected applications in structures, transportation and geomechanics. Use of computer software. Emphasis on problem solving.

**CIVE 5602 [0.5 credit] (CVG 7141)****Advanced Computer-Aided Design**

Representation and processing of design constraints (such as building codes and other design rules); decision tables; constraint satisfaction. Automatic integrity and consistency maintenance of design databases; integrated CAD systems. Introduction to geometric modeling. Introduction to artificial intelligence.

Also offered at the undergraduate level, with different requirements, as CIVE 4500, for which additional credit is precluded.

**CIVE 5605 [0.5 credit] (CVG 7143)****Design of Steel Bridges**

Basic features of steel bridges, design of slab-on-girder, box girder and truss bridges. Composite and non-composite design. Introduction to long span suspension and cable-stayed bridges. Discussion of relevant codes and specifications.

**CIVE 5606 [0.5 credit] (CVG 7144)****Design of Concrete Bridges**

Concrete and reinforcing steel properties, basic features of concrete bridges, design of superstructure in reinforced concrete slab, slab-on-girder and box girder bridges, an introduction to prestressed concrete bridges, design of bridge piers and abutments. In all cases the relevant provisions of Canadian bridge codes are discussed.

**CIVE 5607 [0.5 credit] (CVG 7145)****Introduction to Bridge Design**

Limit states design of highway bridges; methods of analysis, design and evaluation procedures of superstructure components; design codes; design loads and load factors; concrete deck design; load distributions; computer analysis; impact and dynamics; fatigue and brittle fracture; construction bracing; load capacity rating of existing bridges.

**CIVE 5609 [0.5 credit] (CVG 7170)****Fundamentals of Fire Safety Engineering**

The fire safety system, including social, economic and environmental issues; description of the fire safety regulatory system and the governing building codes and standards. This includes the global fire safety system in a facility and active fire protection systems; detection, suppression, smoke management.

Precludes additional credit for CIVE 5707 (2001-2002).

**CIVE 5610 [0.5 credit] (CVG 7171)****Fire Dynamics I**

Fundamentals of combustion including material and energy balances, chemical thermodynamics, kinetics, premixed and diffusive burning. Advanced topics in the theory of combustion, flame propagation, efficiency of combustion, and the physico-chemical properties of combustible material.

Precludes additional credit for CIVE 5705 (2001-2003).

**CIVE 5611 [0.5 credit] (CVG 7173)****People in Fires**

Review of the work presented by the founders in the field of human behaviour in fire. Introduction to the basic notions of perception, cognition, information processing, decision-making and problem solving. Behavioural concepts such as panic, commitment, affiliation, familiarity and role are discussed.

Precludes additional credit for CIVE 5708 (2001-2003).

**CIVE 5612 [0.5 credit] (CVG 7174)****Fire Modeling**

Fire modeling and its role in fire safety engineering.

Review of the main modeling techniques used in Fire Safety Engineering: network, zone and Computational Fluid Dynamics (CFD).

Precludes additional credit for CIVE 5802 (2002-2003).

**CIVE 5613 [0.5 credit] (CVG 7172)****Fire Dynamics II**

Fire dynamics from ignition through heat transfer to growth and spread of fires and their suppression. Factors such as containment and its role in the dynamics of fires and explosions are covered.

Precludes additional credit for CIVE 5803 (2002-2003).

Prerequisite(s): CIVE 5610 Fire Dynamics I.

**CIVE 5614 [0.5 credit] (CVG 7175)****Design for Fire Resistance**

Behaviour of materials and structures at elevated temperatures; fire-resistance tests; fire-resistance ratings; building code requirements; real-world fires; assessing the fire resistance of steel, concrete and wood building assemblies.

Precludes additional credit for CIVE 5709 (2001-2003).

**CIVE 5615 [0.5 credit] (CVG 5320)****Fire Behaviour of Materials**

Fundamentals and scientific aspects of materials behaviour during fires, material specifications, thermal and mechanical properties, fire hazards of materials, structural fire response, residual strength, failure criteria, mechanisms of flame retardancy, and standards and testing protocols.

**CIVE 5705 [0.5 credit] (CVG 7300)****Topics in Structures**

Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5706 [0.5 credit] (CVG 7301)****Topics in Structures**

Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5707 [0.5 credit] (CVG 7302)****Topics in Structures**

Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5708 [0.5 credit] (CVG 7303)****Topics in Structures**

Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5709 [0.5 credit] (CVG 7304)****Topics in Structures**

Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5800 [0.5 credit] (CVG 7305)****Topics in Geotechnique**

Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5801 [0.5 credit] (CVG 7306)****Topics in Geotechnique**

Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5802 [0.5 credit] (CVG 7307)****Topics in Geotechnique**

Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5803 [0.5 credit] (CVG 7308)****Topics in Geotechnique**

Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5804 [0.5 credit] (CVG 7309)****Topics in Geotechnique**

Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5805 [0.5 credit] (CVG 7310)****Topics in Transportation**

Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5806 [0.5 credit] (CVG 7311)****Topics in Transportation**

Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5807 [0.5 credit] (CVG 7312)****Topics in Transportation**

Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5808 [0.5 credit] (CVG 7313)****Topics in Transportation**

Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5809 [0.5 credit] (CVG 7314)****Topics in Transportation**

Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

**CIVE 5810 [0.5 credit]****Topics in Fire Safety**

Courses in special topics related to fire safety, not covered by other graduate courses.

**CIVE 5900 [1.0 credit] (CVG 6000)****Civil Engineering Project**

Students enrolled in the program M.Eng. by project will conduct an engineering study, analysis, or design project under the general supervision of a member of the Department.

**CIVE 5901 [0.0 credit] (CVG 7314)****Master's Seminar**

The series consists of presentations by graduate students or external speakers. Graduate students in the Civil Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.

**CIVE 5906 [0.5 credit] (CVG 6108)****Directed Studies 1**

Prerequisite(s): open only to students in a Civil Engineering Master's program.

**CIVE 5909 [2.5 credits] (CVG 5909)****M.A.Sc. Thesis****CIVE 6901 [0.0 credit]****Ph.D. Seminar**

The series consists of presentations by graduate students or external speakers. Graduate students in the Civil Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.

**CIVE 6902 [0.0 credit] (CVG 9998)****Ph.D. Comprehensive Examination**

Graduate students at the Doctoral level in the Civil Engineering program are required to successfully complete written and oral comprehensive examinations in subject areas determined by the student's advisory committee.

**CIVE 6906 [0.5 credit] (CVG 6109)****Directed Studies 2**

Prerequisite(s): open only to students in the Civil Engineering Ph.D. program.

**CIVE 6909 [8.0 credits] (CVG 9999)****Ph.D. Thesis**