Course Outline

# Numerical Methods in Geotechnical Engineering

CIVE 5800 (Winter 2025)

Department of Civil and Environmental Engineering
Carleton University

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| **Instructor:** Mehdi Pouragha | **Lectures:** Thu 14:35 - 17:25 |
| EDC 4530, mehdi.pouragha@carleton.ca | **Location:** Consult your timetable or here |

## Description and Topics

Special Topic in Geotechnique: Numerical techniques for analysing problems in geomechanics. The topics include:

- Introduction and Mathematical and Mechanics Preliminaries
  *Vector and matrix calculus, Gradient, Divergence, and Jacobian, Newton-Raphson Method*
- Introduction to computational coding in MATLAB
- Time integration, Computational elastoplasticity
  *Explicit vs. Implicit methods, Return mapping, Yield functions, 1D and 2D formulation*
- Finite Difference Method
  *Harmonic oscillator, 2D diffusion problems*
- Initial Value Problems
  *Vibrating String, Stability of the numerical solution*
- Introduction to Finite Element Methods (1D)
  *Local vs global stiffness, Stiffness matrix assembly, Shape functions*

## Learning Outcomes

- **Apply advanced mathematical techniques:** Demonstrate proficiency in vector and matrix calculus, understand concepts like gradient, divergence, and Jacobian, and use the Newton-Raphson method for solving nonlinear equations.
- **Develop computational coding skills:** Write and debug scripts in MATLAB to solve engineering problems efficiently.
- **Analyze time integration methods:** Distinguish between explicit and implicit methods, implement computational elastoplasticity concepts (e.g., return mapping and yield functions), and solve 1D and 2D problems.
- **Implement the Finite Difference Method (FDM) for Basic Problems:** Solve harmonic oscillator and 2D diffusion problems using FDM and evaluate numerical accuracy.
- **Solve Initial Value Problems (IVPs):** Analyze vibrating string dynamics and assess the stability of numerical solutions for time-dependent problems.
- **Understand the fundamentals of Finite Element Methods (FEM):** Construct and solve 1D FEM problems, including assembling global stiffness matrices and using shape functions.

**Text book(s)/Learning Materials and Their Costs**

Students are not required to purchase textbooks or other learning materials for this course. The books below can be used as additional resources.

- Simo, J. C., & Hughes, T. J. (2006). *Computational Inelasticity* (Vol. 7). Springer Science & Business Media.
  *Vector and matrix calculus, Gradient, Divergence, and Jacobian, Newton-Raphson Method*
- Langtangen, H. P., & Linge, S. (2017). *Finite difference computing with PDEs: a modern software approach*. Springer Nature.
- Fish, J., & Belytschko, T. (2007). *A first course in finite elements* (Vol. 1). New York: John Wiley & Sons.

**Evaluation**

- The assessment is based on three individual assignments given during the semester. Based on their preference, the students can complete the assignments using either MATLAB or Python.
- Weights: First assignment 30%, Second assignment 35%, Third assignment 35%.
- A minimum of 50% in each assignment is required to obtain a passing grade.

Students who claim extenuating circumstances defined in the Academic Consideration Policy, as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases. This must occur no later than three (3) days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule. Consult Section 4.4 of the University Calendar.

**Required Knowledge (**IMPORTANT**)**

This course requires a working knowledge of: vector and matrix algebra, basics of elastic and plastic strains, basics of material models, and basics of differential equation (simple ODEs and PDEs). Basic skills of computer coding and computational algorithms are also required.

**Copyright of Materials**

**Academic Accommodation**

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

**Academic Accommodations for Students with Disabilities:** The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca.

You should request your academic accommodations in the Ventus Student Portal, for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

**Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see the Senate Policy on Accommodation for Student Activities (PDF).

**Pregnancy Obligation:** Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (PDF).

**Religious Obligation:** Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (PDF).

**Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit the Sexual Violence Prevention & Survivor Support.