COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

CIEN 4253 Finite Elements in Geotechnical Engineering
Fall 2015

CLASS SESSIONS
Wednesday 7:00-9:30pm

INSTRUCTOR
Professor: Dr. Steve WaiChing Sun, 614 Mudd, wsun@columbia.edu
Office Hour: Friday 10:00-12:00PM or by appointment

TEXTBOOK
The monographs listed below are highly recommended. However, course materials may differ from those covered in the textbooks. Lecture notes will be provided.

1. *Plasticity: Modeling and Computation*, R.I. Borja, Springer, 2013.
2. *Computational Methods for Plasticity: Theory and Applications,* E.A. de Souza Neto, D. Peric, D.R.J. Owen, John Wiley & Sons, 2008.

COURSE DESCRIPTION
The objective of this course is to teach students deriving, implementing and using finite element models for modern geotechnical engineering applications. This master level course will cover a range of essential modeling skills such as techniques for solving nonlinear finite element models, hyperelasticity, plasticity and poro-plasticity, critical sate soil mechanics, implicit and explicit dynamics for geotechnical earthquake problems, analysis of soil-structure interaction and enrichment methods for strong discontinuities.

NOTE
1. The course outline in page 2 is tentative and subject to change.
2. Homework problem sets will be assigned on a regular basis.
3. To complete the final students, students will require basic knowledge of MATLAB or other computer language.

PREREQUISITES
Required: ENME E3332x or equivalent course(s).

COURSE LEARNING OBJECTIVES
Students who successfully complete this course will be able to:
- Develop a basic understanding of constitutive responses of geological materials.
- Learn and apply basic mathematical and computational techniques to characterize constitutive responses at material points and at field scales.
- Master the essential skills to interpret experiential data.

ASSESSMENT AND GRADING POLICY
Student grades will be based on:
Take-home Mid-term 50%
Final Project 50%

COURSE OUTLINE

- **Introduction (2 week)**
  - Historical background
  - Computer structure of a nonlinear finite element programs.
  - Overview of strong, weak and Galerkin forms and linearization.
  - Typical workflow for introducing customized model in commercial codes.
- **Plasticity in one dimension (1 week)**
  - One-dimensional implicit finite element.
  - Newton's method for numerical solution procedures.
  - Notion of isotropic and kinematic hardening in one-dimensional problem.
  - Damage and plasticity in 1D.
- **Pressure-insensitive J2 plasticity (2 weeks)**
  - Deviatoric plasticity
  - Deviatoric Flow rule
  - Isotropic, kinematic and combined hardening
  - Plastic dissipation
- **Integration algorithm for J2 plasticity (3 weeks)**
  - Radial return algorithm
  - Consistent tangent operator
  - Introduction to general return mapping algorithm
- **Isotropic function and pressure-sensitive plasticity (3weeks)**
  - Spectral representation
  - Mohr-Coulomb model
  - Drucker-Prager model
  - Return mapping algorithm in principal directions
- **Advanced topics (3 weeks)**
  - Cap plasticity
  - Hyper-elasticity and hyper-elasto-plasticity
  - Critical state plasticity
  - Volumetric, deviatoric and mixed hardening rules
  - Stability and dispersion analyses
  - Implicit and explicit dynamics
  - Strong discontinuities

EXAMINATION AND FINAL PROJECT

One take home mid-term exam, which weighs 50% of the total grade will be given. 50% of the total grades will be based on the final project. Students will develop their final projects based on their own research interest and discipline. A presentation session will be scheduled for each student to present the findings at the end of the semester.

HOMEWORK

One homework assignment will be set (approximately) every three weeks. The homework will not be graded.

POLICIES AND EXPECTATIONS

Academic Integrity

Students are required to adhere to the Codes of Conduct, Community Standard and Academic Integrity, available online at http://apam.columbia.edu/files/seasdepts/applied-physics-and-applied-math/pdf-files/SEAS_conduct.pdf

Disability Access

In order to receive disability-related academic accommodations, students must first be registered with the Office of Disability Services (ODS). Students who have, or think they may have a disability are invited to contact ODS for a confidential discussion at 212.854.2388 (V) 212.854.2378 (TTY), or by email at disability@columbia.edu. If you have already registered with ODS, please speak to your instructor to ensure that s/he has been notified of your recommended accommodations by Lillian Morales (lm31@columbia.edu), the School's liaison to the Office of Disability Services.