Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9512a –Finite Element Method (Theory and Applications)

Course Outline – Fall 2022

DESCRIPTION

This course introduces the basis of the finite element method and its application in solving engineering problems, mainly structural applications. The course is designed to achieve the following objectives:

- Apply mathematical knowledge to understand the basic theory of the finite element method in linear analysis.
- Understand modelling aspects and techniques for 1-D, 2-D and 3-D problems.
- Learn about modelling of simple and complex structural systems, develop their mathematical, and computational models.
- Understand preprocessing steps, solver (solution step), postprocessing steps, and model validation.
- Learn how to model different structural systems using commercial programs like SAP2000, ETABS, and ANSYS.

ENROLLMENT RESTRICTIONS

Enrollment in this course is restricted to graduate students with bachelor's degree in Civil Engineering, as well as any student that has obtained permission to enroll in this course from the course instructor as well as the Graduate Chair (or equivalent) from the student's home program.

PREREQUISITE

Bachelor's degree in Civil Engineering.

INSTRUCTOR CONTACT INFORMATION

- Course instructor: Dr. Ayman El Ansary, P.Eng.
- Email address: ayman.elansary@uwo.ca
- Office: Spencer Engineering Building (SEB 3026A)
- Lecture hours: 3 hours lecture per week – Fridays 9:30 am – 12:30 pm (Room: TBD)
- Office hours: Weekly office hours will be held either in person or via Zoom
- *Administrative Support*: SEB 3118

COURSE FORMAT

This course will be delivered **in-person**.

"In the event of a COVID-19 resurgence during the course that necessitates the course delivery moving away from face-to-face interaction, all remaining course content will be delivered entirely online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will not change. Any remaining assessments will also be conducted online at the discretion of the course instructor"

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1	Introduction to the finite element method (FEM)		
	Lecture 1: Background – Chapter 1 - What is FEM - Applications of FEM - Basic types of elements - Degrees of freedom Lecture 2: Chapter 1 (cont.) - Review of basic equations for bar and beam problems.	• Lecture 1: Three (3) hours in-person class • Lecture 2: Three (3) hours in-person class • Reading material (Course notes – Chapter 1) will be posted on course site OWL.	Weeks 1-2 Fridays, **Sept. 9th** & 16th.
	Lecture 3: Chapter 2 - Principle of minimum potential energy and approximate analysis.	• Lecture 3: Three (3) hours in-person class • Reading material (Course notes – Chapter 2) will be posted on course site OWL. • Help session (office hour)	Week 3 Friday, Sept. 23rd
2	Finite element formulation and application of bar elements (uni-dimensional element)		
	Lecture 4: Chapter 3 - Displacement field and shape functions used in the formulation of a bar element. - Derive the stiffness matrix as well as load vector due to various load conditions acting on a bar element. - Develop numerical models for uni- dimensional problems using SAP2000.	• Lecture 4: Three (3) hours in-person class • Reading material (Course notes – Chapter 3) will be posted on course site OWL. • Help session (office hour)	Week 4 Friday, Sept. 30th
3	Finite element formulation and application of plane trusses		
	Lecture 5: Chapter 4 - Concept of transformation of vectors in two different coordinate systems in the plane - Learn about transformation matrix and relationship between local and global systems. - Derive the stiffness matrix for a bar arbitrarily oriented in the plane. - Develop numerical models for plane truss problems using SAP2000.	• Lecture 5: Three (3) hours in-person class • Reading material (Course notes – Chapter 4) will be posted on course site OWL. • Help session (office hour)	Week 5 Friday, Oct. 7th

Topic #	Description	Learning Activities	Tentative timeline
4	Finite element formulation and applicationof beam elements		
	Lecture 6: Chapter 5 - Displacement field and shape functions used in the formulation of a beam element. - Derive the stiffness matrix as well as loadvector due to various load conditions acting on a beam element. - Develop numerical models for beam andplane frame problems using SAP2000.	• Lecture 6: Three (3) hours in-person class • Reading material (Course notes – Chapter 5) will be posted on course site OWL. • Help session (office hour)	Week 6 Friday, Oct. 14th
5	Introduction to theory of elasticity		
	Lecture 7: Chapter 6 - This section will enable the student to understand the basic equilibrium and kinematic equations, the constitutive relations as well as the potential energy expression for 2-D plane stress and planestrain elasticity problems.	• Lecture 7: Three (3) hours in-person class • Reading material (Course notes – Chapter 6) will be posted on course site OWL. • Help session (office hour)	Week 7 Friday, Oct. 21st
6	Introduction to various types of 2-D elements		
	Lecture 8: Chapter 7 - Recognize various types of elements used to solve 2-D plane problems. Develop numerical models to solve Plane-stress and plane-strain problems using SAP2000 and ANSYS.	• Lecture 8: Three (3) hours in-person class • Reading material (Course notes – Chapter 7) will be posted on course site OWL. • Help session (office hour)	Week 8 Friday, Oct. 28th
	Reading Week (No class)		**Week 9 Friday, Nov. 4th No class**
7	Practical consideration in modelling and introduction to 3-D modelling using SAP2000		
	Lecture 9: Chapter 8 - In this section, general guidelines for finite element modelling are presented Lecture 10: Chapter 9 - Use the commercial program SAP2000 to develop a three-dimensional computer model to idealize a cable-stayed bridge for the evaluation of internal forces.	• Lecture 9: Three (3) hours in-person class • Reading material (Course notes – Chapter 8) will be posted on course site OWL. • Lecture 10: Three (3) hours in-person class • Reading material (Course notes – Chapter 9) will be posted on course site OWL. • Help session (office hour)	Weeks 10-11 Fridays, Nov. 11th, and 18th

Topic #	Description	Learning Activities	Tentative timeline
8	Introduction to 3-D modelling using ETABS		
	Lecture 11: Chapter 10 - Use the program ETABS to develop three-dimensional computer models to idealize high-rise buildings under differenttypes of loading. Lecture 12: Chapter 10 (cont.)	• Lecture 11: Three (3) hours in-person class • Reading material (Course notes – Chapter 10) will be posted on course site OWL. • Lecture 12: Three (3) hours in-person class • Help session (office hour)	Weeks 12-13 Fridays, Nov. 25th, and Dec. 2nd

SPECIFIC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	30%	• Assignments • Final Project • Final Examination	• Understanding of advanced concepts and theories • Awareness of important current problems in the field of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	10%	• Final Project	• Ability to conduct critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment
Application of knowledge	30%	• Assignments • Final Project • Final Examination	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use coherent approach to design a particular engineering system using existing design tools
Professional capacity / autonomy	10%	• Final Project	• Awareness of academic integrity • Ability to implement established procedures and practices in the coursework • Defends own ideas and conclusions • Integrates reflection into his/her learning process
Communication skills	10%	• Final Project	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of limits of knowledge	10%	• Final Project	• Awareness of the need of assumptions in complex scientific analyses and their consequences • Understanding of the difference between theoretical and empirical approaches • Ability to acknowledge analytical limitation due to complexity of practical problems

COURSE MATERIAL

Prepared class notes will be made available through the course website on OWL at http://owl.uwo.ca/, along with other useful reference material and data for assignments.

Lecture notes and any posted demonstration videos are copyrighted to the instructor and legally protected. Do not post these videos and lecture notes on any other website or online forums. The recording of the live/synchronous lectures of the course without the permission from the course instructor is prohibited.The illegal posting and sharing of the copyrighted course content could be subjected to legal actions.

REFERENCES

1) *A First Course in the Finite Element Method, D.L. Logan, 2nd Ed., PWS Kent Publ. Co., Boston, 1992.*
2) *Introduction to Finite elements in Engineering, T.R. Chandruptla and A.D. Beleguner, 2nd Ed., PrenticeHall., NJ, 1992.*

COMPUTING

Several assignments will involve computer modelling of structures using the commercial programs SAP2000V19 and ETABS V19. The full version of these programs is available at the PC lab in the Engineering building. Remote access to the computer lab and the software license server will be provided. Instructions on how to remotely access the software license will be posted on course OWL site. In addition, few assignments will involve numerical simulations using the commercial software ANSYS Workbench 2022 R2. A free student license can be downloaded through this link: Download Ansys Student | Workbench-based Simulation Tools

Terms of use: Free student downloads are for educational use only and may only be used for self-learning, student instruction, student projects, and student demonstrations.

UNITS

SI units will be used in lectures and examinations

ASSESSMENT

Assessment Type	**Material Covered**	**Tentative Due Date***	**Weight**
Homework Assignments (six)	Topics 1, 2, 3, 4, 5, 6, 7	Check course calendar	30%
Participation	In person and posted questions in course OWL site "Forums"	Weekly activity	5%
Final Project	Topic 8	Dec. 15th, 2022	30%
Final Exam (Open Book)	Topics 1 - 8	Dec. 9th, 2022	35%
Oral Exam	Final Project	Dec. 19th & 20th	50% of project weight

* The shown dates are an approximate guide for students and are subject to change.

Activities in which collaboration is permitted:

- *Participation using course OWL site "Forums"*: Weekly forums will be posted on the course site OWL. Each week students are expected to interact with the course content and with each other by posting questions/responding to existing questions on OWL "Forums". Minimum expectation regarding this participation activity is at least one posting per week. Group discussion using "Forums" regarding course material and topics covered in lectures is permitted.
- *Final Project*: Students will be divided into groups (2 members per group). Collaboration between ***only*** group members is permitted. One final project report is required from each group.

Activities in which students must work alone (collaboration is not permitted):

- Homework Assignments
- Final Project
- Final Exam

USE OF ENGLISH

In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

CHEATING, PLAGIARISM/ACADEMIC OFFENCES

Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence at the following website: https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf

CONDUCT

Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

HEALTH/WELLNESS SERVICES

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. To schedule an appointment with the counsellor, contact Kristen Edwards (khunt29@uwo.ca) via confidential email and you will be contacted by our intake office within 48 hours to schedule an appointment.

Students who are in emotional/mental distress should refer to Mental Health@Western: http://www.uwo.ca/uwocom/mentalhealth/ for a complete list of options about how to obtain help.

SICKNESS

Students should immediately consult with the instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate, or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at:
https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html

ACCESSIBLE EDUCATION WESTERN (AEW)

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program.

Graduate students with disabilities (for example, chronic illnesses, mental health conditions, mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): http://academicsupport.uwo.ca/accessible_education/index.html

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.