Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9719 – Finite Element Analysis for Solids II

Course Outline – Winter 2024

DESCRIPTION

The objective of this course is to provide graduate students with the basic concepts and applications of some of the advanced topics in finite element modelling: iso-parametric elements; plate and shell problems; buckling and nonlinear problems.

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

CEE-9512A or an equivalent first graduate course in the finite element method.

INSTRUCTOR CONTACT INFORMATION

- Course instructor: Dr. Ashraf El Damatty, Ph.D., P.Eng.
- Email address: damatty@uwo.ca
- Office: Spencer Engineering Building (SEB 3081)
- Lecture hours: 3 hours lecture per week
- 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
1	Introduction to cartesian tensor analysis	
	Lecture 1: Chapter 1 - Vectors transformation - Transformation of coordinates - Concept of tensors - Tensors Algebra	• Lecture 1: Three (3) hours in-person class • Reading material (Course notes – Chapter 1) will be posted on the course site OWL.
2	Theory of elasticity	
	Lecture 2: Chapter 2 - Constitutive relations - Plane elasticity problems - Beam bending problems	• Lecture 2: Three (3) hours in-person class • Reading material (Course notes – Chapter 2) will be posted on the course site OWL.
3	Convergence criteria in the finite element method	
	Lecture 3: Chapter 3 - Strain free rigid body modes - Constant strain modes - Displacement continuity - Spatial isotropy - Convergence and order of accuracy of beam elements	• Lecture 3: Three (3) hours in-person class • Reading material (Course notes – Chapter 3) will be posted on the course site OWL.
4	Isoparametric 2-D elements	
	Lecture 4: Chapter 4 - Four node quadrilateral element - Eight-node isoparametric element - Six-node isoparametric triangular element - General 2-D plane elasticity using potential energy/ virtual work Lecture 5: Chapter 4 (cont.) - Eight node quadrilateral element - Gauss-Quadrature numerical integrations	• Lecture 4: Three (3) hours in-person class • Reading material (Course notes – Chapter 4) will be posted on the course site OWL. • Lecture 5: Three (3) hours in-person class • Reading material (Course notes – Chapter 4) will be posted on the course site OWL.
5	Thin plate bending problems	

	Lecture 6: Chapter 5 - Theory - Finite element formulation - Rectangular plate bending elements - Non-conforming elements Lecture 7: Chapter 5 (cont.) - Conforming elements - Comparison between conforming and nonconforming elements - Adding of stiffness - Perpendicular plates	• Lecture 6: Three (3) hours in-person class • Reading material (Course notes – Chapter 5) will be posted on the course site OWL. • Lecture 7: Three (3) hours in-person class • Reading material (Course notes – Chapter 5) will be posted on the course site OWL.
6	Thick plate bending problems	
	Lecture 8: Chapter 6 - Mindlin plate theory - Finite element formulation - Locking phenomenon - Reduced integration technique	• Lecture 8: Three (3) hours in-person class • Reading material (Course notes – Chapter 6) will be posted on the course site OWL.
7	Analysis of thin shells	
	Lecture 9: Chapter 7 - Theories and concepts Lecture 10: Chapter 7 (cont.) - Shell elements based on membrane and bending actions	• Lecture 9: Three (3) hours in-person class • Reading material (Course notes – Chapter 7) will be posted on the course site OWL. • Lecture 10: Three (3) hours in-person class • Reading material (Course notes – Chapter 7) will be posted on the course site OWL.
8	Analysis of thick shells	
	Lecture 11: Chapter 8 - Degenerated shell elements - Degenerated consistent subparametric triangular element	• Lecture 11: Three (3) hours in-person class • Reading material (Course notes – Chapter 8) will be posted on the course site OWL.
9	Buckling problems	
	Lecture 12: Chapter 9 - Concepts of bifurcation and limit loads - Linearized buckling analysis using finite element method	• Lecture 12: Three (3) hours in-person class Reading material (Course notes – Chapter 9) will be posted on the

		course site OWL.
10	Introduction to nonlinear finite element analysis	
	Lecture 13: Chapter 10 - Large displacement formulation - Solution technique for nonlinear problems - Newton-Raphson method - Displacement control analysis - Arc-length method	• Lecture 13: Three (3) hours in-person class Reading material (Course notes – Chapter 10) will be posted on the course site OWL.

***Note that there will be no lectures during reading week**

SPECIFIC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	30%	• Assignments • Final Project	• Understanding of advanced concepts and theories • Awareness of important current problems in thefield of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	10%	• Final Project	• Ability to conduct a critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analysesof complex problems using established techniques/principles and judgment
Application of knowledge	30%	• Assignments • Final Project	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use a coherent approach to design a particular engineering system using existing designtools
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 theoreticaland empirical approaches • Ability to acknowledge analytical limitations due to the 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 websites or online forums. Recording of the live/synchronous lectures of the course without permission from the course instructor is prohibited.The illegal posting and sharing of the copyrighted course content could be subjected to legal action.

REFERENCES

1) *Cook R., "Concepts and Applications of Finite Element Analysis", 4th Ed., John Wiley & Sons, 2007.*
2) *Zienkiewicz R., Olek C., and Taylor R., "The Finite Element Method for Solid and Structural Mechanics, Volume 1", Elsevier, 2005.*
3) *Zienkiewicz R., and Taylor R., "The Finite Element Method, Volume 2: Solid Mechanics.", Butterworth-Heinemann, 2000.*
4) *Bathe K., "Finite Element Procedures", Klaus-Jurgen Bathe, 2006*

COMPUTING

Several assignments will involve computer modelling of structures using the commercial programs ANSYS and ABAQUS.

UNITS

SI units will be used in lectures and assignments

ASSESSMENT

Assessment Type	Material Covered	Tentative Due Date*	Weight
Homework Assignments	Topics 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Check course calendar	45%
Class Participation	Topics 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Weekly activity	5%
Final Project	Topics 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Check course calendar	50%
Oral Exam	Final Project	Check course calendar	30% of the project's weight

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.

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

- Homework Assignments
- Final Project

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 the information above and ask the 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. Information on how to schedule an appointment with the counsellor is available at:

https://www.eng.uwo.ca/undergraduate/academic-support-and-accommodations/Student-Wellness-Counselling.html

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.