Faculty of Engineering and Design
Department of Mechanical and Aerospace Engineering

Course number	Course Title	Term	Academic Year
MECH4604	**Finite Element Methods**	**Winter**	**2022**

Course Instructor	Office	Email	Office Hours
Dr. Mehdi Eshaghi	Virtual	MehdiEshaghi@cunet.carleton.ca	Monday 4:00 – 5:30 pm Wednesday 4:00 – 5:30 pm

CLASS SCHEDULE

Days	Time	Location
Mondays and Wednesdays	2:35 pm - 3:55 pm	Mackenzie Building 3380 and Online

PREREQUISITES

MAAE 3202 and (MAAE 3300 or MECH 3310)

CONDITIONS SPEFIC FOR REMOTE TEACHING AND ASSESMENT

1. All students are expected to have access to a computer with following capabilities:
   a. reliable internet connection
   b. camera and microphone (your computer and/or cellphone)
   c. document scanning application such as Adobe Scan app

2. All students should install VPN for remote desktop access to Carleton University computer labs. You need ANSYS Mechanical APDL and MATLAB in this course.

3. Course instructor reserves the right to conduct an individual oral examination to verify student's response to online exam questions.

4. Plagiarism (copying and handing in for credit someone else's work) is a serious instructional offense that will not be tolerated.

COURSE CALENDAR DESCRIPTION

Finite element methodologies with emphasis on applications to stress analysis, static deflection and heat transfer using the simplest one- and two-dimensional elements are illustrated. Direct equilibrium, variational and Galerkin formulations are employed to extract FE model of different structures such as springs, trusses, beams, frames, and plates. Applications of ANSYS and MATLAB software in the finite element analysis of the systems and structures are demonstrated.

COURSE LEARNING OBJECTIVES

At the end of this course, you will be able to:

- formulate finite element problems using the Direct Method, Minimum Total Potential Energy Method, and the Method of Weighted Residuals.
- formulate the stiffness (conductance) matrix for simple one-dimensional linear and quadratic elements; beam elements; and frame elements.
- assemble element matrices into the governing system of equations, apply boundary conditions and solve.
- formulate the stiffness matrix.
- perform basic structural analyses using Ansys Mechanical finite element software.

GRADING POLICY

MIDTERM EXAM (March 2, up to video lecture #20)	**25%**
ANSYS EXAM	**15%**
PROJECT	**10%**
FINAL EXAM	**50%**

Remarks:

- You may be randomly selected after the midterm, ANSYS and final exams for individual zoom meeting to explain your solutions. Failure in explaining your solution not only affects the grade of that particular exam, but also affects your final mark.
- You need to obtain a passing mark (50%) for the final exam in order to pass the course.
- No alternate, supplemental or make-up term test will be given.
- There will be no fixed relationship between marks and letter grades.
- Events beyond the control of the instructor may require changes to this outline.
- All lectures time and evaluation period are based on Ottawa time zone.

SOFTWARE

- ANSYS Mechanical APDL (https://www.ansys.com/academic/students)
- MATLAB

TEXTBOOKS

- FINITE ELEMENT ANALYSIS, Theory and Application with ANSYS, Third or Fourth Edition, Saeed Moaveni, Prentice-Hall Inc., 2008, ISBN 978-0-13-189080-8.
- A First Course in the Finite Element Method, Fifth or Sixth Edition, Daryl Logan, Thomson-Engineering, 2016. ISBN-13: 978-1305635111.
- Mechanical Vibrations, Fifth Edition, Singiresu S. Rao, Pearson; 2010. ISBN-13: 978-0133840803
- ANSYS Tutorial Release 14, Kent Lawrence, SDC Publications, 2012, ISBN 978-1-58503-761-2.
- Finite Element Analysis, Third Edition, S.S. Bhavikatti, New Age International Publishers, 2016, ISBN-13: 978-8122436716

Schedule				
Week	**Day**	**Date**	**Materials**	**Video #**
1	Monday	Jan 10	Introduction to FEM	
	Wednesday	Jan 12	Spring Element, Global Stiffness Matrix	1,2
2	Monday	Jan 17	Potential Energy Approach, Problem on Spring Element	3,4
	Wednesday	Jan 19	Trusses, Example on Bar Element	5,6
3	Monday	Jan 24	Transformation of Element Matrices and Vectors, Example on Truss Structure	7,8
	Wednesday	Jan 26	Assembling Stiffness Matrix	9
4	Monday	Jan 31	Introduction to Matlab, Example on Truss #2	10,11
	Wednesday	Feb 2	Truss APDL	12
5	Monday	Fab 7	Collocation Method, Subdomain Galerkin Least Square	13,14
	Wednesday	Feb 9	Matlab Tutorial #2, Axial Members Potential Energy Approach	15,16
6	Monday	Feb 14	Beam Structure, FE Analysis of Beam	17,18
	Wednesday	Feb 16	Work Equivalence Method, Example on Beam Structure	19,20
7	Monday	Feb 21	Winter Break	
	Wednesday	Feb 23		
8	Monday	Feb 28	Review Lecture	
	Wednesday	March 2	Midterm (up to end of video #20)	
9	Monday	March 7	Frame Structure, Example on Frame	21,22
	Wednesday	March 9	Beam APDL, Frame APDL	23,24
10	Monday	March 14	Linear Elements, Quadratic Element, Cubic Element	25,26,27
	Wednesday	March 16	Higher Order Elements, Coordinate Systems, Isoparametric Elements	28,29,30
11	Monday	March 21	Matlab Tutorial 3, Thin Plate Relations	31,32
	Wednesday	March 23	Plate Element Shape functions, Plate Stiffness Matrix	33,34
12	Monday	March 28	Example on Plate	35
	Wednesday	March 30	Plate APDL, Plate Workbench	36,37
13	Monday	April 4	Vibration Analysis of Beam Structure	
	Wednesday	April 6	Vibration Analysis of Plate Structure	
14	Monday	April 11	Vibration Analysis of Plates and Beams Using Ansys	
	Wednesday	April 13	Review Lecture	

SYLLABUS

Spring Element (Logan, Chapter 2)

- Spring Element
- Global Stiffness Matrix
- Potential Energy Approach

Trusses (Logan, Chapter 3)

Transformation of Element Matrices and Vectors (Rao, Chapter 12)

Assembling Stiffness Matrix (Rao, Chapter 12)

Weighted Residual Methods (Moaveni, Chapter 1)

- Collocation Method
- Subdomain, Galerkin and Least Square Methods

Axial Members Potential Energy Approach (Moaveni, Chapter 4)

Beam Structure (Logan, Chapter 4)

- FE Analysis of Beam
- Work Equivalence Method

Frame Structure (Logan, Chapter 5)

One-dimensional Elements (Moaveni, Chapter 5)

- Linear Elements
- Quadratic Element
- Cubic Element
- Higher Order Elements
- Coordinate Systems
- Isoparametric Elements

Thin Plates (Bhavikatti, Chapter 15)

- Thin Plate Relations
- Plate Element Shape functions
- Plate Stiffness Matrix

Vibration Analysis of Beams and Plate Structures (Rao, Chapter 12)

ANSYS Mechanical APDL (Lawrence and Moaveni)

General Regulations:

Attendance:
Students are expected to attend all lectures. The University requires students to have a conflict-free timetable. For more information, see the current *Undergraduate Calendar, Academic Regulations of the University, Section 1.2, Course Selection and Registration and Section 1.5, Deregistration.*

Appeal of Grades:
The processes for dealing with questions or concerns regarding grades assigned during the term and final grades is described in the *Undergraduate Calendar, Academic Regulations of the University, Section 2.7, Informal Appeal of Grade and Section 2.8, Formal Appeal of Grade.*

Academic Integrity:
Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: https://carleton.ca/registrar/academic-integrity/. This site also contains a link to the complete Academic Integrity Policy that was approved by the University's Senate.

Classroom Behaviour:
Students are required to observe standards of behaviour expected in a university environment and in the profession of engineering. Excessive talking among students, texting, watching movies, etc. during lectures is disruptive of the learning atmosphere, and is a distraction for the instructor and the other students. Please maintain a quiet, attentive and engaging classroom environment.

Academic Accommodation:
You may need special arrangements to meet your academic obligations during the term. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://www.carleton.ca/equity/ For an accommodation request, the processes are as follows:

- **Pregnancy or 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 see https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf

- **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 for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your ***Letter of Accommodation*** at the beginning

of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*). **Requests made within two weeks will be reviewed on a case-by-case basis.** After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website (www.carleton.ca/pmc) for the deadline to request accommodations for the formally-scheduled exam (*if applicable*).

- **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: https://carleton.ca/sexual-violence-support/.

- **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 https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf