Faculty of Engineering

Department of Mechanical Engineering

COURSE OUTLINE

MECH 420/563 Finite Element Applications

Term – SUMMER 2016 (201605)

Instructor	**Office Hours**
Dr. Brad Buckham	Days: T
Phone: 250.721.6035	Time: 1:00pm-3:00pm
E-mail: bbuckham@uvic.ca	Location: EOW 531

List all prerequisites and co-requisites: MECH 320, 330

LECTURE DATE(S)

MECH 420: A01 (30586) MECH 563: A02 (30587)	Days: T, W, F	Time: 11:30am-12:30pm	Location: COR B112

TUTORIAL SECTIONS

Section: T01	Days: Th	Time: 2:30-3:30	Location: COR B112

TA Name	**E-mail**	**Office**
Reza Harirforoush	rharirfo@uvic.ca	EOW 131

Required Text
Title: A First Course in the Finite Element Method
Author: Daryl L. Logan
Publisher/Year: 2011

COURSE OBJECTIVES

MECH 420/563 – Finite Element Applications: focuses on the solution to differential equations that arise in the field of applied mechanics using the Finite Element Method (FEM). The course addresses problems of elasticity (in bars, beam, grids, and plate elements), heat transfer and structural dynamics. By taking a multi-physics approach, the course intends to illustrate the generality of the modern FEM.

FE analysis is first introduced as a numerical solution process for deformation analysis of elastic structures. For these problems, the finite elements are derived using the direct stiffness/displacement method (DSM). The formulation of bar, beam, frame, and grid finite elements will be demonstrated and these elements will be used to solve force-deformation problems. The assembly of these elements is illustrated in tutorial examples and reinforced through problems assigned from the course textbook.

In the latter stages of the class, the generalization of the finite element method will be presented. A succinct overview of virtual work, or potential energy, element formulations and the method of weighted residuals facilitates the application of the finite element method to plane stress and strain, heat transfer and structural dynamics problems. At the end of the course, an introduction to time domain numerical integration will be given. This introduction will show how the FEM and numerical integrators are used together to perform dynamics simulation.

Learning Outcomes next page

The lectures will attempt to cover the material presented in the textbook as follows:

Text Section #	Topics Covered	Dates (mm.dd)
	<u>Module I</u> – Bars and Beams.	
(1.1 - 1.7, A.1-A.5)	FEM introduction; course introduction.	05.03 – 05.04
(2.1-2.5)	Introduction to the Direct Stiffness Method: spring elements, assembly, boundary conditions.	05.03 - 05.10
(3.1 - 3.9)	Truss elements, global stiffness, rotation operators, skewed supports.	05.10 - 05.13
(4.1 - 4.6, D.1)	Beam elements, distributed loads, nodal hinges.	05.17 - 05.20
	<u>Module II</u> – Frames, Grids, and the CST.	
(5.1 - 5.4)	Torsion in beams, plane frame & spatial grids.	05.24 – 06.03
(2.6, 3.10-3.12, 4.7-4.8, E.1 supp.)	Virtual work, strain energy, variational formulations, weighted residual formulations.	06.07 - 06.17
(6.1 - 6.5)	Plane stress and strain elements, the CST, body forces and surface tractions.	06.21 – 06.24
	<u>Module III</u> – Natural , Heat Transfer, structural dynamics	
(6.6, 81.-8.3, 10.5)	Higher Order 2D Elements (LST, Q4, Q8).	06.28 – 07.06
(10.1-10.4)	Isoparametric element formulations; Guassian quadrature.	07.08 - 07.12
(13.1-13.8, 14.1, 14.3)	1D and 2D Heat transfer	07.13 - 07.22
(16.2-16.3, 16.6 + supp.)	Structural dynamics: natural modes and numerical integration of time domain equations.	07.26 – 07.29

OFFICE HOURS

Students are welcome, and encouraged, to make inquiries regarding lecture material, assignment problems, and project work at any time. However, to ensure the instructor's availability, students should contact the instructor in advance to set a meeting time. To make efficient use of meeting times, students are encouraged to discuss problems with their colleagues and come as a group to meet with the instructor. Office Hours provided on the first page of this outline are tentative. Should a reorganization of the instructor office hours be required, notice will be provided in lecture period.

LEARNING OUTCOMES

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

1. Execute the <u>direct stiffness method</u> to calculate the deformation of trusses, frames and grids, including:
   a. Decompose, conceptually, a structure into a logical collection of idealized solid elements.
   b. Infer appropriate displacement interpolating polynomials based on the assumed loading conditions.
   c. Derive force-displacement element equations for bar, beam, frame and grid elements.
   d. Assemble multiple element equations to form a single global system of equations.
   e. Anticipate the structure of assembled equations based on the node and element numbering scheme.
   f. Apply force and displacement boundary conditions at the node points of the element assembly to solve global equation sets.
   g. Recover internal forces and deformations within the structure.
   h. Judge the validity of solutions and recognize limitations imposed by the various steps in the solution process.
2. Apply the principle of stationary potential energy to form the general finite element equations for structural elements.
3. Form displacement interpolating polynomials for 3 and 4 node plane stress and plane strain finite elements.
4. Derive plane stress and plane strain finite element equations using the general finite element equations.
5. Relate the method of weighted residuals to the principle of stationary potential energy in structural problems.
6. Apply the method of weighted residuals to two-dimensional heat transfer problems and structural dynamics.
7. Use open quadrature formulae to numerically evaluate integrals within the weighted residuals method.
8. Determine natural frequencies of a structure using a finite element model.
9. Numerically integrate finite element equations in time to trace the motion of a structure.
10. Use commercial software in the solution of assembled finite element equations, including:
   a. Use ANSYS in the solution of spatial frame/truss deformation and plane stress problems.
   b. Conduct convergence analysis using ANSYS output.
   c. Manipulate matrix equations (row and column operations) in Matlab.
   d. Use Matlab to assemble and solve finite element equations.

ASSESSMENT METHODS

Weight & Date(s) of Assessments:	**MECH 420 Weight**	**MECH 563 Weight**	**Due Date**
Assignments	%25	%20	See “Assignments” section below
Module 1 Test	%25	%20	06.15
Module 2 Test	%25	%20	07.20
Module 3 Test	%25	%20	TBA†
	%0	%20	TBA‡

†The Module 3 Test will be held during the final exam period and will be scheduled by the Office of the Registrar
‡The MECH 563 project materials will be due near the end of the final examination period. Exact date is TBA

NOTES:

1. The final grade obtained from the above marking scheme for the purpose of GPA calculation will be based on the percentage-to-grade point conversion table as listed in the current Undergraduate Calendar.

2. There will be no supplemental examination for this course.

ASSIGNMENTS

Five problem sets will be distributed over the course of the term. Each assignment will have two parts.

Part I of each assignment will be formed from end of section problems from the course textbook or problems created by the course instructors. Solutions to Part I problems will be prepared by hand and **must be submitted on Engineering Computation Paper** which is available in the UVic bookstore. Note that some Part I problems include many degrees of freedom and are best solved using the MATLAB command window to calculate and manipulate the system matrices (while still reporting the solution process on paper).

In Part II of each assignment, problems will be solved using ANYS or custom Matlab functions. The ANSYS assignments will provide students exposure to an industry standard FEA package. The Matlab problems will require students to apply fundamental programming skills acquired in earlier courses and investigate how finite element models can be assembled and solved in a simple programming environment.

Tutorial documents will be prepared for each Part II problem and provided via email or the course website Part II of each assignment will be graded based on submission of a short report that is to be submitted along with the Part I work. The report requirements will be stated in the problem's tutorial document.

Students should try to get an early start on each assignment and make consistent progress during the respective assignment period. The anticipated periods for the assignments are:

Assignment #	Topics	Start	Due (5 pm)
1	Truss elements, assembly, rotation matrices	05.06	05.20
2	Beams, distributed loads, nodal hinges	05.24	06.07
3	Frames and grids, weighted residual formulations		06.29
4	CST elements (plane stress & plane strain)		07.15
5	Heat transfer, structural dynamics		07.29

PROJECTS: (MECH 563 only))

The MECH 563 graduate curriculum will follow that of the MECH 420 course. However, there will be an additional project component to the course. The additional project is intended to allow the graduate student to investigate the execution of more advanced methods in FEM.

Information on project requirements, topic selection and required reporting will be distributed no later than the third week of scheduled lectures.

COURSE LECTURE NOTES

Unless otherwise noted, all course materials supplied to students in this course have been prepared by the instructor and are intended for use in this course only. These materials are NOT to be re-circulated digitally, whether by email or by uploading or copying to websites, or to others not enrolled in this course. Violation of this policy may in some cases constitute a breach of academic integrity as defined in the UVic Calendar.

COURSE POLICIES & IMPORTANT DATES:

Exams and quizzes:

1. The Module tests are open-book. The materials permitted during exams and quizzes are: pen, pencil, eraser, straightedge, calculator **without communication capabilities**, **and the student's course notebook**. Materials prepared outside the scope of the course (other textbooks, solution manuals, other student work, etc) are not permitted.

2. The Module I test will be held on Wednesday June 15 between 6:30-8:30pm in room ECS 125.

3. The Module II test will be held on Wednesday July 20 between 6:30-8:30pm in room ECS 125.

4. The Module III exam will be held in the final exam period and will be scheduled by the Office of the Registrar.

HW Assignments:

1. Hand-written (HW) assignments must be done on Engineering computation paper to be accepted. **Any other paper will be rejected**.

2. 20% of assignment grades will be allocated to presentation.

3. HW Assignments must be submitted to the MECH 420/563 Dropbox located on first floor of the Engineering Lab Wing by 5:00pm of the due date. **Late HW Assignments will not be accepted.**

4. The solutions to the HW Assignments will be posted on the course website as soon as the due time has passed.

Calculators:

1. Self-contained (with no wireless communication capability) calculators are allowed in all exams. The grading of assignment and test problems will be based heavily on the methodology applied in calculating the final solution. A significant proportion of assignment and test marks are awarded based on a clear and logical description of the solution process. Using such grading criterion, specification of the correct numerical solution constitutes only a portion of the problem's allotted marks.

GENERAL INFORMATION

Note to Students:

Students who have issues with the conduct of the course should discuss them with the instructor first. If these discussions do not resolve the issue, then students should feel free to contact the Chair of the Department by email or the Chair's Secretary to set up an appointment.

"**Attendance**

Students are expected to attend all classes in which they are enrolled. An academic unit may require a student to withdraw from a course if the student is registered in another course that occurs at the same time….

An instructor may refuse a student admission to a lecture, laboratory, online course discussion or learning activity, tutorial or other learning activity set out in the course outline because of lateness, misconduct, inattention or failure to meet the responsibilities of the course set out in the course outline. Students who neglect their academic work may be assigned a final grade of N or debarred from final examinations.

Students who do not attend classes must not assume that they have been dropped from a course by an academic unit or an instructor. Courses that are not formally dropped will be given a failing grade, students may be required to withdraw and will be required to pay the tuition fee for the course." UVic Calendar, (2015) http://web.uvic.ca/calendar2015-09/FACS/UnIn/UARe/Atte.html

Accommodation of Religious Observance (AC1210)
http://web.uvic.ca/calendar2015-09/GI/GUPo.html

Discrimination and Harassment Policy (GV0205)
http://web.uvic.ca/calendar2015-09/GI/GUPo.html

Faculty of Engineering, University of Victoria
Standards for Professional Behaviour

"It is the responsibility of all members of the Faculty of Engineering, students, staff and faculty, to adhere to and promote standards of professional behaviour that support an effective learning environment that prepares graduates for careers as professionals…."

You are advised to read the Faculty of Engineering document Standards for Professional Behaviour which contains important information regarding conduct in courses, labs, and in the general use of facilities.
http://www.uvic.ca/engineering/current/undergrad/index.php#section0-23

Cheating, plagiarism and other forms of academic fraud are taken very seriously by both the University and the Department. You should consult the Undergraduate Calendar for the UVic policy on academic integrity.

Policy on Academic Integrity
http://web.uvic.ca/calendar2015-09/FACS/UnIn/UARe/PoAcI.html