UNSW AUSTRALIA

Course Outline

Semester 1, 2015

Never Stand Still | Faculty of Engineering | School of Mechanical and Manufacturing Engineering

MMAN4410

Finite Element Methods

Contents

Course Outline

MMAN4410 Finite Element Methods

1. COURSE STAFF

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Consultation

Consultation concerning this course is available during the software laboratories. Outside of these hours the convenor and demonstrators can be contacted through the Moodle platform; either via a forum or through direct messaging. *Any questions about course content and assessment that are not of a private nature should be directed to the appropriate Moodle forum*. Any *personal* queries about course administration can be directed to Garth via direct email or Moodle direct message.

2. COURSE DETAILS

Summary of the course

This course will train you to analyse real world structural mechanics problems using the finite element method. You will be introduced to the mathematical basis of finite element analysis, on which nearly all structural analysis software is built. You will learn how to apply commercially available finite element software to solve real-world engineering problems. The course will cater to the specific challenges of engineers across all mechanical disciplines (Aerospace, Manufacturing, Mechanical, Mechatronic and Naval). Any student wishing to extend their structural analysis skills should take this course.

Aims of the course

The primary aim of this course is to train you to solve complex engineering structural mechanics problems with finite element analysis. The course will provide deep insight into the operation of finite element analysis software by teaching you the underlying computational methods involved. You will be taught to execute a detailed finite element study including planning, modelling, meshing, solving, evaluating results and validating against real world data.

Units of credit

This is a 6 unit-of-credit (UoC) course, and involves 4 hours per week (h/w) of face-to-face contact. The UNSW website states “The normal workload expectations of a student are approximately 25 hours per semester for each UoC, including class contact hours, other learning activities, preparation and time spent on all assessable work.”

For a standard 24 UoC in the semester, this means 600 hours, spread over an effective 15 weeks of the semester (thirteen weeks plus stuvac plus one effective exam week), or 40 hours per week, for an average student aiming for a credit grade. Various factors, such as your own ability, your target grade, etc., will influence the time needed in your case. Some students spend much more than 40 h/w, but you should aim for not less than 40 h/w on coursework for 24 UoC.

This means that you should aim to spend not less than about 10 h/w on this course, i.e. an additional 6 h/w of your own time. This should be spent in making sure that you understand the lecture material, completing the set assignments, further reading about the course material, and revising and learning for the examination.

Relationship to entire program

Finite Element Methods (MMAN4410) is a professional elective. It is a capstone for structural mechanics courses (MMAN2400, MMAN3400, AERO3410, NAVL3410), however the fundamentals of finite element theory are mathematical (MATH2XXX). Finite element analysis is a crucial tool in most modern structural design and will be a very valuable asset for you in design courses (MECH4100, AERO41XX, NAVL41XX, etc.).

If you want to specialise as a structures engineer or designer, then MMAN4410 is an excellent companion for other closely related courses:

- Fundamental and Advanced Vibration Analysis
- Fundamentals of Acoustics and Noise
- Mechanics of Fracture and Fatigue
- Composite Materials and Mechanics

Student learning outcomes

At the conclusion of this course, students should be able to:

1. Apply fundamental finite element analysis techniques to solve simple engineering problems
2. Explain the underlying mathematics behind finite element analysis software solvers
3. Plan and execute appropriate finite element analyses to solve a range of solid mechanics and other engineering problems.
4. Perform a detailed finite element study to investigate a real world engineering problem

Graduate attributes

Please refer to UNSW graduate attributes:
https://my.unsw.edu.au/student/atoz/GraduateAttributes.html

UNSW aspires to develop graduates who are rigorous scholars, capable of leadership and professional practice in a global community. The university has, thus, articulated the following Graduate Attributes as desired learning outcomes for ALL UNSW students. UNSW graduates will be:

1. Scholars who are:

   a) understanding of their discipline in its interdisciplinary context (*)
   b) capable of independent and collaborative enquiry (*)
   c) rigorous in their analysis, critique, and reflection (*)
   d) able to apply their knowledge and skills to solving problems (*)
   e) ethical practitioners
   f) capable of effective communication (*)
   g) information literate (*)
   h) digitally literate (*)

2. Leaders who are:

   a) enterprising, innovative and creative (*)
   b) capable of initiating as well as embracing change
   c) collaborative team workers

3. Professionals who are:

   a) capable of independent, self-directed practice (*)
   b) capable of lifelong learning (*)
   c) capable of operating within an agreed Code of Practice

4. Global Citizens who are:

   a) capable of applying their discipline in local, national and international contexts
   b) culturally aware and capable of respecting diversity and acting in socially just/responsible ways
   c) capable of environmental responsibility

Graduate attributes targeted and developed in this course are marked with an asterisk (*).

3. TEACHING STRATEGIES

Your learning in the course will be supported by best practice teaching methodologies. The baseline approach to teaching in the course is based on modified Bloom's Taxonomy and the formation of assessments is based on SOLO Taxonomy. New teaching strategies and teaching technologies are deployed every year to ensure that the course is as up-to-date as possible to leading teaching standards.

This course includes two face-to-face teaching methods:

1. Lectures to introduce fundamental finite element analysis concepts
2. Software laboratories to apply fundamental concepts in common finite element analysis packages

In order to maximise the utility of the course for different streams of the students in MMAN (Mech, Aero, Naval, etc), software laboratory sets will be provided which cater to the individual disciplines in the most appropriate software for each discipline. For example, Aerospace Engineering employers request that the students are familiar with Patran/Nastran whereas ANSYS is more appropriate for Mechanical Engineers. The school supports both packages and will for the foreseeable future.

In addition to the face-to-face teaching, a range of blended techniques will be used through Moodle to engage the students with independent learning. The major assignment, for example, includes a significant research component which will allow each individual student to study an engineering problem which is specific to their own interests.

4. RATIONALE FOR INCLUSION OF CONTENT AND TEACHING APPROACH

Finite Element Methods are the most commonly used tools to solve structural mechanics problems in engineering. The general FE method can also be applied to a range of other physical problems that can be described by differential equations (magnetostatics, thermal analyses, etc.). It is critical that any graduate wishing to specialise in any form of structural engineering is well versed in the theory and application of the finite element method to a range of engineering problems. MMAN4410 provides the opportunity for students to acquire these skills.

Finite Element Methods is a final year professional elective and as such you will be expected to exercise and develop your professional competencies during the course. MMAN4410 is constructed in a way that you must be self-driven and seek answers to your problems from a wide variety of sources. Do not expect to have problems resolved immediately by the course coordinator upon initial request.

Two formal classes are given to support your learning in the course:

- Lectures
- Hands-on simulations (software laboratories)

Lectures will run for half the semester and provide an introduction to the theoretical framework on which the FE method is built. The lectures will not cover every aspect of such a large discipline, but will instead focus on those topics which give you as a student the maximum opportunity to pursue further reading in the field.

Hands-on simulations will cover the application of the FE method to a range of structural and non-structural problems in a commercial finite element package. It is extremely important that you are confident and competent using commercial FE packages to solve complex engineering problems.

A strong emphasis will be placed on reporting in MMAN4410. As a professional engineer you are judged primarily on instances of written and verbal communication (technical reports, design documents, meetings, etc.). The most important skill that any engineer can acquire is the ability to communicate the results of an analysis in a clear, concise and unambiguous manner.

5. ASSESSMENT

In this course there are currently no plans to use the school assignment boxes for physical assignments; all assignments will be submitted digitally. If there are technological difficulties which force the use of physical assignment copies, they must include a School cover sheet which is available from the school website and are to be submitted before *11am* on the due date so that they can be processed before close of business.

Online submissions are required to be submitted via Moodle. No cover sheet is required as all assignments will be identified through your Moodle account. *All digital assignments are due by 5pm on the due date.* An additional allowance will be granted automatically to submit assignments until 11:55pm without penalty, but you accept any risk of technical difficulties with submission. *If you try to submit between 5pm and 11:55pm and Moodle does not accept the submission for any reason the assignment will be considered late.*

All submissions are expected to be neat and clearly set out. Calculations, where they are necessary, should be shown professionally in any report; *scans of hand calculations will not be accepted.* The submission of online material should follow the instructions given on the appropriate Moodle page.

Late submissions will *receive zero marks* but should still be submitted. It is always worth submitting late assessment tasks when possible. Completion of the work, even late, may be taken into account in cases of special consideration.

In addition to any criteria specified in the assignment hand-outs, the following criteria will be used to grade assignments:

1. For reports:
    - Identification of key facts and the integration of those facts in a logical development.
    - Clarity of communication: this includes development of a clear and orderly structure and the highlighting of core arguments.
    - Sentences in clear and plain English: this includes correct grammar, spelling and punctuation.
    - Correct referencing of source materials.

2. For numerical calculations:

    - Accuracy of numerical answers.
    - Use of diagrams, where appropriate, to support or illustrate the calculations.
    - Use of graphs, were appropriate, to support or illustrate the calculations.
    - Use of tables, where appropriate, to support or shorten the calculations.
    - Neatness.

Marks

The final course mark will be determined by the following weightings:

Task	**Mark %**	**Learning Outcomes Assessed**	**Graduate Attributes Assessed**	**Tasks or Submissions Due in Week(s)**
Assignment 1 – FE Fundamentals	10	1	1(c,f)	4
Assignment 2 – Good FE Practice	10	3	1(b-c,f-h), 3(a)	8
FE Fundamentals Exam	30	1,2	1(c-d,f-g)	9-10 (TBC)
Major Project	50	3,4	1(a-d,f-h), 2(a), 3(a-b)	9, During Exam, 13
Total	**100**			

In order to pass the course, you must achieve an overall mark of at least 50%.

Assignment 1 – FE Fundamentals

Finite Element Analysis is numerically intensive and is exclusively solved by powerful computers for all real engineering problems. Modern software packages hide the majority of complex tasks from the user. Unfortunately, this level of automation can lead to the false belief that FEA is an infallible tool. It is important that you as an engineer understand the computations being conducted on your behalf in order to understand their limitations and possible errors that can appear in your analyses.

This assignment will teach you the fundamentals of the Finite Element Method through hand calculations and simple programming.

Assignment 2 – Good FE Practice

Proper planning, execution and reporting of analyses are crucial skills for any engineering graduate. When using FE analysis techniques to solve and report on a problem, there are countless opportunities to exercise poor technique. At best, poor technique detracts from the quality of the solution and at worst leads to dangerous or negligent results.

During this assignment you will study a very simple engineering problem using FEM but will learn best practice techniques to ensure you produce high quality results and write an excellent report.

FE Fundamentals Exam

A mid-session exam will use a combination of short answer questions, derivations and long form calculations to test your understanding and application of FE fundamentals.

You will need to bring a UNSW approved calculator to the examination:
https://student.unsw.edu.au/exam-approved-calculators-and-computers

Major Project

A flexible major project will be given to you at the beginning of semester and will form the largest component of the assessment for the course.

The topic of the project will be up to you to decide, but must represent a current FE simulation challenge in the scientific literature or from a relevant engineering discipline. The assessment will be broken into pieces to ensure that adequate progress is being made throughout the semester:

- Topic selection guidance and approval (Friday Week 5)
    - A topic title and 200 word outline will be submitted to the demonstrators for approval by Friday Week 5.
    - Must be submitted and passed to progress
- Draft findings (Friday Week 9)
    - A small report will be submitted by Friday Week 9 with preliminary findings, which will be peer assessed.
    - The peer-assessment process will be worth 10 of the 50 marks for the major project.
- Exam Question (During mid-session)
    - One question of the mid-session exam will be devoted to your major project. This question will assess the depth of your understanding of the FE method you are applying for your major project.

    - The exam question will contribute 5/50 marks for your major project. These marks are not included in the mid-session marks.
- Final Report (Friday Week 13)
    - A major report on you FE project will be due in Week 13
    - The final report will be worth 35 marks.

Special Consideration and Supplementary Assessment

For details of applying for special consideration and conditions for the award of supplementary assessment, see *Administrative Matters for All Courses*, available from the School website.

In this course, supplementary assessment will only be provided for the final examination and is still at the discretion of the course authority. Special consideration for other assessment tasks, if granted, will allow the assessment task to be removed from the final grade and the other grades will be adjusted accordingly.

6. ACADEMIC HONESTY AND PLAGIARISM

Plagiarism is using the words or ideas of others and presenting them as your own. Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website which provides essential information for avoiding plagiarism: https://student.unsw.edu.au/plagiarism

There is a range of resources to support students to avoid plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one. Information is available on the dedicated website Plagiarism and Academic Integrity website (link above).

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in a honours thesis) even suspension from the university. The Student Misconduct Procedures are available here: https://student.unsw.edu.au/conduct

Further information on School policy and procedures in the event of plagiarism is presented in a School handout, *Administrative Matters for All Courses*, available on the School website.

7. COURSE SCHEDULE

Lectures

Week	Name	Date	Topics
1	**Introduction to FEM**	**2-Mar**	Introduction to FEA; Discretisation; FE Terminology; Stiffness Matrices for Bars, Trusses and Beams; Element Library Introduction.
2	**Numerical Solution Procedure**	**9-Mar**	Applying Loads and Boundary Conditions; Assembly; Solving for Nodal Displacements; Constitutive Laws; Interpolation of Stress and Strain
3	**The Element Library**	**16-Mar**	2D Triangles and Quads; Shells; 3D Tets and Hexes; Solid Shells; Isoparametric Elements; Quadratic and Higher Order Elements; Benefits and Limitations of Different Element Types
4	**Good FE Practice**	**23-Mar**	A General FE Problem Solving Approach; Modelling Assumptions; Meshing Strategy; Convergence; Validation; Sources of Error in FE; Computational Resources; Interfacing with CAD; FE Reporting
5	**Buckling and Non-linear Analyses**	**30-Mar**	Eigenvalue Solutions; Linear Buckling; Material Non-linearity; Geometric Non-linearity and Buckling; Iteration Schema and Incremental Analysis; Contact
Break		**6-Apr**	
6	**Vibration and Transient Analyses**	**13-Apr**	Modal Analysis; Harmonic Analysis; Other Vibration Solutions; Transient Solutions and their Applications; Choice of Time Discretisation
7	**Advanced FE Topics**	**20-Apr**	Mechanisms and Rigid Dynamics; Modelling Composites; Thermal Analyses; Fluid-Structure Interaction; Magnetostatics; Soil Modelling

8. RESOURCES FOR STUDENTS

Learning Management System

Moodle LMS, https://moodle.telt.unsw.edu.au/ will be used for this course. Lecture notes, software laboratories, assignments, links and forums will be available on Moodle. Moodle is a powerful tool that you are encouraged to use for all course needs.

Textbooks

Recommended Resources

- Cook, R. D., Malkus, D. S., Plesha, M. E., Witt, R. J. (2002). Concepts and Applications of Finite Element Analysis, 4th Ed, John Wiley & Sons.
- Chandrupatla, T. R., Belegundu, A. D. (2011) Introduction to Finite Elements in Engineering, 4th Ed, Prentice Hall (Pearson)

Other Resources

If you wish to explore any of the lecture topics in more depth, then other resources are available and assistance may be obtained from the UNSW Library. One starting point for assistance is the library website: www.library.unsw.edu.au/.

9. COURSE EVALUATION AND DEVELOPMENT

Finite Element Methods is a brand new course for 2015. In response to the School of Mechanical and Manufacturing Engineering Curriculum Review Project in 2013, it was decided that the finite element method needed to be offered as a professional elective to all MechEng students on a level playing field. As a result, a number of smaller FE offerings in different streams were discontinued (MECH3540, AERO3410, AERO4410, etc.). This course takes the best elements of the previous offerings as well as a broad swathe of new content specifically designed to fit the course.

As this is a new course there will no doubt be some teething problems. Your experience as a student should still be a highly constructive and enjoyable one.

10. ADMINISTRATIVE MATTERS

You are expected to have read and be familiar with *Administrative Matters for All Courses*, available from the school guideline website: http://www.engineering.unsw.edu.au/mechanical-engineering/forms-and-guidelines.

This document contains important information on student responsibilities and support, including special consideration, assessment, health and safety, and student equity and diversity.

Equity and diversity

Students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course convenor prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Student Equity and Disabilities Unit (SEADU) by phone on 9385 4734,

email seadu@unsw.edu.au or via the website www.studentequity.unsw.edu.au. The office is located on the Ground Floor of the Goodsell building (F20).

Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

G Pearce
February 2015