ME EN 7540 ADVANCED FINITE ELEMENTS

15263, Spring 2010, Tues. & Thurs 03:40 PM-05:00 PM, WEB L114, 3 credit hours
Website: WebCT (webct.utah.edu)

Instructor: Rebecca Brannon, 2134 MEB, email via WebCT, 801-581-6623 (Cell: 801-662-8340)
Office hours: Mondays 3:00PM-5:00PM (or by appointment, or drop-in *if instructor is available*)

Course description

Applications to problems from solid, heat transfer, and fluid mechanics, and advanced elements. Consideration of nonlinear and time-dependent problems.

Course Overview

As a follow-up to a first course in the finite element method (FEM) where you were introduced to basic principles and hands-on use of commercial FEM software, this course provides a deeper understanding of commercial software by reviewing the underlying theory in greater depth and breadth. The goal is to improve your ability to correctly and cautiously apply the Finite Element Method in your research career. Potential topics include error analysis, advanced elements, geometric and material nonlinearity, with applications to continuum solids/fluid mechanics and heat transfer. Activities will include theoretical analyses, computer programming, and a Term Project applying commercial (or research) FEM software of your selection to solve a problem of particular interest to you in your own research.

Prerequisites: Graduate status, ME EN 5510, 6510 or similar introductory course in FEM *in which you learned how to run at least one commercial FEM code*, vector calculus, linear algebra, exposure to ordinary and partial differential equations and numerical analysis, ability to program in Matlab, C/C++, Python, Fortran, or other scientific programming language.

Textbook (optional):

Erik G. Thompson (2004) Introduction to the Finite Element Method: Theory, Programming and Applications. Wiley, 2004. (ISBN-10: 0471267538, ISBN-13: 978-047126753)

Supplemental reading:

1. Reddy, J.N. (2004) An Introduction to Nonlinear Finite Element Analysis by J. N. Reddy, Oxford University Press, ISBN 019852529X.;
2. Zienkiewicz and R.L. Taylor (2005) The Finite Element Method for Solid and Structural Mechanics, Sixth Edition (Hardcover)
3. Simo, J.C., and Hughes, T.J.R. (1998) Computational Inelasticity, Springer.

Grading:

c= Computer programming Assignments:	20%
h= Other Homework (including commercial code exercises)	25%
m= Midterm Exam	25%
p= Term Project using commercial code(s):	30%
f= Final Exam (Wednesday, May 5, 2010, 3:30-5:30pm)	30%
TOTAL=	**130% minus 15% from two lowest = 100%**

Formula: SCORE = $(20c+25h+25m+30p+30f - 15L_1 - 15L_2)/100$, where L_1 and L_2 are your lowest two scores among the five categories c, h, m, p, and f (each of which are themselves on a 100 point scale). Exception: academic misconduct will result in a zero score that does not count as L_1 or L_2 and might result in a zero score for the entire course. The score is assigned a letter grade according to the following table.

0-59	60-62	63-66	67-69	70-72	73-76	77-79	80-82	83-86	87-89	90-92	93-96	97-100
E	D-	D	D+	C-	C	C+	B-	B	B+	A-	A	A+

The instructor reserves the right to lower the score required for any letter grade. There is no curve.

Course Objectives: *You are expected to...*

- Demonstrate understanding of the governing equations considered in this course, including associated data (boundary/initial conditions, forcing functions, material properties, etc.) and limits of applicability. Demonstrate understanding of various numerical methods available to solve these equations, with deep understanding of the FEM approach along with error analysis and other means of solution verification. **Assessment: Homework and Exams.**
- Use good computer programming practices to write your own small codes for using FEM to solve simple (e.g., one-dimensional) problems. Professionally document the governing equations, the source code, and investigations of solution quality (e.g., by comparing against analytical solutions, convergence studies, user-input checks etc.). **Assessment: programming assignments.**
- As an individual or up to three-person team, propose a problem of interest in your graduate research, and solve it by using commercial FEM software (or, with instructor's approval, Univ. of Utah research FEM software). This exercise should be conducted as if it were being done for an actual business customer. Therefore, it must begin with a project proposal (including estimates of the number of hours to be spent by each participant and a timeline for milestones), followed by status report memos, a final report, and final presentation. The final report must include a table of contents, acknowledgements, cited references, and other elements that are conventional in technical project reports. The body of the final report must include: an introduction stating why this problem is of engineering interest, discussion of the applicability of the governing equations, problem data, simulation results, error analysis, discussions and conclusions regarding the extent to which the problem was solved, opportunities for follow-up work, and an appendix or attachments containing input files and step-by-step instructions that are detailed enough to allow other individuals to duplicate your results. **Assessment: Project proposal, status memos, final report, and presentation.**

Homework Policies

A homework assignment is a set of problems. A problem of ordinary difficulty is worth 100 points. Easy problems are worth less. Hard problems are worth more. A homework problem will be given a grade of zero if it is incoherent or if it fails to follow the following format:

Problem: What is given, and what is required?

Solution: word explanations *must* accompany each equation and the final result should be boxed.

Discussion: Make intelligent and thoughtful comments about the problem, perhaps pointing out the principles that the problem illustrates. If applicable, the discussion must include verification and validation analysis.

Unless otherwise announced, homework is due one week after it is assigned. Late homework is accepted at a 10% penalty per day (if it is three days late, for example, then the highest you can get is 70%). Moreover, to accommodate the occasional missed homework, the following formula will be used to assign a homework score at the end of the class:

$$\text{homework grade (on scale from 0 to 100)} = 50\left[1+\frac{h}{H}-\text{Exp}\left(\frac{-h}{H-h}\right)\right],$$

where h is your total amassed homework points and H is the total number of available homework points.

All assignments will be given through Blackboard Vista (WebCT). All homework must be submitted electronically to WebCT as a PDF document. Scanners are available in the CADE lab. If technical difficulties prevent you from uploading a document before the due date cutoff time, then call or send a text message to the instructor (801-662-8340) explaining the problem. If this evidence of due diligence is not provided within three hours of the uploading deadline, no accommodations will be made. No more than three accommodations will be made for uploading difficulties that are not experienced by the majority of the rest of the class.

Collaboration on concepts and procedures is expected and encouraged, but you must ultimately do the work yourself and present the work *in your own words*. Academic misconduct may result in a failing grade, dismissal from the program or the University, revocation of the student's degree or certificate, or other sanctions. See the Student Handbook for further details.

Can you boost your grade by doing extra work? Yes, but not at the end of the semester as a last-minute attempt to fix a low average. Bonus points will be given if you supplement the *regular* assignments with extra analyses or simulations far beyond what was required in the assignment. The due date for bonus points is the same as the due date for the assignment itself (no last-minute bonus points are available).

Important dates (these are unofficial for your convenience – for official dates see http://www.sa.utah.edu/regist/calendar/datesDeadlines/Spring2010.htm)

Classes begin ..... Monday, January 11
Last day to register without a permission code ..... Monday, Jan 18
Martin Luther King Jr. Day ..... Monday, January 18
Last day to drop (delete) classes ..... Wednesday, January 20
→ DRAFT term project proposal..... Thursday, January 21
Last day to elect CR/NC/audit ..... Monday, January 25
Completed project proposal ..... Thursday, February 4
President's day ..... Monday, February 15
Project status report memo ..... Thursday, February 18
→ MIDTERM EXAM ..... Tuesday, March 2
Project status report memo ..... Thursday, March 4
Last day to withdraw ..... Friday, March 5
→ Project status report memo ..... Thursday, March 18
Spring break ..... Mon-Sat, March 22-27
→ Project DRAFT report ..... Thursday, April 8
→ Project FINAL report ..... Thursday, April 15
Project presentations ..... April 20 & 22
Last day to reverse CR/NC option ..... Friday, April 23
Classes end ..... Wednesday, April 28
Final exam ..... Wednesday, May 5, 2010, 3:30-5:30pm
Grades available to students ..... Tuesday, May 18

Tentative timetable *(very likely to change based on student interests and ability)*

Date	Topic	Reading (optional)
1/12	Introduction and Review of basic FEM terminology	1-23, notes
1/14	Collocation and least squares	4-6, notes
1/19	Galerkin's method and Ritz Method	notes
1/21	Finite element formulations (review)	10-18, notes
1/26*	Calculus of variations	23-35, notes
1/28	shape functions and stiffness matrix	35-40, notes
2/2	numerical methods (quadrature and Newton solvers)	notes
2/4	boundary conditions	40-42 and notes
2/9	Programming the FEM for 1-D problems	44-50, notes
2/11	linearized continuum mechanics and linear elasticity	221-260, notes
2/16	Review of second-order linear ODEs	53-81, notes
2/18	Two dimensional shape function and gradient	83-89, notes
2/23	Programming 2-D problems	83-91, notes
2/25	review and catch-up	
3/2	**MIDTERM EXAM**	
3/4	Time integration	191-201
3/9	stability analysis	notes
3/11	verification (error analysis)	notes
3/16	nonlinear continuum mechanics and nonlinear elasticity	notes
3/18	mixed methods for complicated constitutive laws	notes
3/30	specialized shape functions	notes
4/1*	the advection-diffusion equation	notes
4/6	programming the advection-diffusion equation	notes
4/8	spectral analysis	notes
4/13	global and local compatibility	notes
4/15	contact algorithms	notes
4/20	**PROJECT PRESENTATIONS**	
4/22	**PROJECT PRESENTATIONS**	
4/27	review and catch-up	

*** Midcourse student survey**

The following COE guidelines are available at the COE website, http://www.coe.utah.edu/current-undergrad/policies_appeals.php .

COLLEGE OF ENGINEERING GUIDELINES

http://www.coe.utah.edu Spring Semester 2010

Appeals Procedures

See the Code of Student Rights and Responsibilities, located in the Class Schedule or on the UofU Web site for more details

Appeals of Grades and other Academic Actions

If a student believes that an academic action is arbitrary or capricious he/she should discuss the action with the involved faculty member and attempt to resolve. If unable to resolve, the student may appeal the action in accordance with the following procedure:

1. Appeal to Department Chair (in writing) within 40 business days; chair must notify student of a decision within 15 days. If faculty member or student disagrees with decision, then,
2. Appeal to Academic Appeals Committee (see http://www.coe.utah.edu/current-undergrad/appeal.php for members of committee). See II Section D, Code of Student Rights and Responsibilities for details on Academic Appeals Committee hearings.

Americans with Disabilities Act (ADA)

The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you need accommodations in a class, reasonable prior notice needs to be given to the instructor and to the Center for Disability Services, 162 Olpin Union, 581-5020 (V/TDD) to make arrangements for accommodations. All written information in a course can be made available in alternative format with prior notification to the Center for Disability Services.

Repeating Courses

When a College of Engineering class is taken more than once, only the grade for the second attempt is counted. Grades of **W, I, or V** on the student's record count as having taken the class. Some departments enforce these guidelines for other courses as well (e.g., calculus, physics). See an advisor or departmental handbook. Students should note that anyone who takes a required class twice and does not have a satisfactory grade the second time may not be able to graduate.

Withdrawal Procedures

See the Class Schedule or web for more details ** Please note the difference between the terms "drop" and "withdraw". Drop implies that the student will not be held financially responsible and a "W" will not be listed on the transcript. Withdraw means that a "W" will appear on the student's transcript and tuition will be charged. **

Drop Period – No Penalty

Students may DROP any class without penalty or permission during the FIRST TEN calendar days of the term (Wednesday, January 20, 2010).

Withdrawal from Full Term Length Classes

Students may WITHDRAW from classes without professor's permission until **Friday, March 5, 2010**. Please note that a "W" will appear on the transcript and tuition will be charged. Refer to Class Schedule, Tuition and Fees for tuition information.

Withdrawal from Session II

See the web page, for details:
http://www.sa.utah.edu/regist/pdfs/2009-2010.pdf

Withdrawals **after March 5th** will only be granted due to **compelling, nonacademic emergencies**. A petition and supporting documentation must be submitted to the Dean's Office, 1610 Warnock Engineering Building or University College (450 SSB) if you are a pre-major. Petitions must be received before the last day of classes (before finals week).

Adding Classes

Please read carefully: All classes must be added within two weeks of the beginning of the semester (deadline: January 25th). Late adds will be allowed January 26th – 29th, requiring only the instructor's signature. Any request to add a class after January 29th will require signatures from the instructor, department, and dean, and need to be accompanied by a petition letter to the Dean's office.

A $50 FEE WILL BE ASSESSED BY THE REGISTRAR'S OFFICE FOR ADDING CLASSES AFTER January 29th. ***

STUDENT SURVEY

This form will be handed out later in the semester. This copy is for you to take notes until then.

Instructions: Circle the number corresponding to your response:
5=strongly agree 4=agree 3=neutral 2=disagree 1=strongly disagree.

1. The pace at which the course is proceeding is appropriate.
   5 4 3 2 1 COMMENTS (state if too fast or too slow):

2. The prerequisites for this course are reasonable.
   5 4 3 2 1 COMMENTS:

3. I (student) know the prerequisite material well enough to focus on new material.
   5 4 3 2 1 COMMENTS:

4. The instructor's use of class time is effective in helping me understand the material covered.
   5 4 3 2 1 COMMENTS:

5. The textbook and/or lecture notes are useful for learning the material covered.
   5 4 3 2 1 COMMENTS:

6. Homework problems are assigned in proper quantities and are of proper difficulty.
   5 4 3 2 1 COMMENTS:

7. The midterm exam was a fair representation of subjects covered and was graded fairly.
   5 4 3 2 1 COMMENTS:

8. The instructor is respectful when pointing out issues or problems with student performance
   5 4 3 2 1 COMMENTS:

9. I believe that my future employers will seek employees skilled in this subject.
   5 4 3 2 1 COMMENTS:

10. I (student) am happy with the *effort* I have put into this course to date.
    5 4 3 2 1 COMMENTS:

11. I (student) am happy with my *performance* in this course to date.
    5 4 3 2 1 COMMENTS:

If I could change one thing about this course (and, of course, if I could justify the change to the taxpayers who subsidize this public institution) it would be...

IS THIS SURVEY MISSING ANY IMPORTANT AREA FOR FEEDBACK?
Please include additional comments, concerns, or suggestions on the back of this page.

ME EN 7540 (ADVANCED FINITE ELEMENTS)
Student information/affirmation sheet

Student's Full Name (print legibly): _____
Name I prefer to go by: _____
UID: _____

Listed here are the FEM code(s) that I can already run to solve structural mechanics and/or thermal sciences problems [if more than one, circle the one that you are most comfortable using]:

_____

Scientific programming language(s) that I can use: _____

I certify that...

☐ I have been given the course information (syllabus), which includes the instructor's name/contact info/office hours, prerequisite requirements, course objectives, evaluation methods, grading policy, course description, important dates, and *tentative* topics list. I further understand that the instructor retains the right to revise the syllabus, with the proviso that students retain a right to reasonable notice of changes.

☐ I understand the course objectives that are listed in the syllabus.

☐ I have satisfied the pre-requisites for taking this course as they are listed in the syllabus.

☐ I understand that my grade will be partially determined by my ability to communicate technical information (such as source-code documentation and written explanations of the governing equations).

_____	_____	_____
Name	Signature	Date

OPTIONAL message to the instructor *(such as what you hope will be covered, potential issues that you anticipate might affect your performance, etc.)*: