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# ME 425-HM1: Finite Element Methods in Mechanical Engineering

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# ME425: Finite Element Methods in Mechanical Engineering

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(Last updated on August 28, 2019)

## Class time and location

Monday and Wednesday, 11:30am - 12:50pm, MEC221

## Credits and contact hours

This course is 3 credits, with 3 lecture contact hours and no lab component.

## Office Hours

Wednesday before class, MEC305, and you can always send an email to make an appointment, or try dropping in.

## Prerequisites

CIS 101, Math 222, and Mech 237.

## Text

Fish and Belytschko. A First Course in Finite Elements. John Wiley & Sons lnc., 2007.

## Grading

Exam 1: 40%, Exam 2: 40%, Project: 15%, Particiaption: 5%.

## Course description

Introduction to central ideas underlying the finite element method in mechanical engineering and its computer implementation. Fundamental concepts such as interpolation functions for one- and two-dimensional elements, bar element method, Galerkin's method, discretization of a model, methods of assembling global matrices, and the final solution techniques for obtaining nodal values. Specific applications to mechanical engineering problems in trusses, beams, heat transfer, plane stress, and plane strain.

## Learning objectives and performance criteria

Students are expected to gain a basic working knowledge of the FEM., through combined lecture and a computer programming exercise. The specific objectives and performance criteria are:

1. Derive 1D element matrix equations for linear elasticity and linear heat transfer. Evaluated on exams and the project: 80% of the students will earn a grade of 70% or better.

2. Derive 2D element matrix equations for linear elasticity and linear heat transfer. Evaluated on exams and the project: 80% of the students will earn a grade of 70% or better.
3. Apply the steps required for FEM solution to a variety of physical systems and obtain engineering design quantities. Evaluated on exams and the project: 80% of the students will earn a grade of 70% or better.
4. Apply lecture knowledge into practice by writing a simple 1D finite element code in Matlab. Evaluated on the project: 80% of the students will earn a grade of 70% or better.
5. Derive 1D element matrix equations for nonlinear heat conduction, as well as constitutively nonlinear elasticity. Evaluated on exams: 80% of the students will earn a grade of 60% or better.

## Policy

The NJIT honor code will be upheld and any violations will be brought to the attention of the dean of students. Also, failure to show for an exam results in a grade of zero, unless the dean of students contacts me otherwise. *Mobile phones and similar electronic devices are expected to remain silent and not in use — the sight of a mobile phone during an exam results in a grade of F for the class.* Only non-programmable calculators are allowed during exams.

## Academic integrity

Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. Cheating is strictly prohibited and devalues the degree that you are working on. As a member of the NJIT community, it is your responsibility to protect your educational investment by knowing and following the academic code of integrity policy that is found here.

Please note that it is the professional obligation and responsibility of faculty to report any academic misconduct to the Dean of Students Office. Any student found in violation of the code by cheating, plagiarizing or using any online software inappropriately will result in disciplinary action. This may include a failing grade of F, and/or suspension or dismissal from the university. If you have any questions about the code of Academic Integrity, please contact the Dean of Students Office at dos@njit.edu.

## Expectation

Students are expected to gain a basic working knowledge of the FEM. This includes the ability to develop a weak form, select element types and interpolation functions, assemble global matrices, and obtain solutions, for 1D and 2D problems. Attention is focused on the mechanical engineering topics of heat transfer and linear elasticity. **This is not a class on how to use commercial finite element software, it is a class on the theory behind the method, accordingly <u>commercial software is not used.</u>**

## Communication

This course will make use of Canvas for dissemination of various materials. Also, you will be regularly contacted via email at your NJIT email address.

## Required background

The finite element method is a particularly robust numerical method for many partial differential equations often encountered in engineering applications. The theory behind the finite element method makes heavy use of ideas and techniques from linear algebra, in particular matrix and vector calculus and algebra. Also, since the finite element method is used for the solutions of partial differential equations, a working knowledge of differential equations is essential.

## Project

An *individual or group* programming project focusing on a simple finite element implementation extending the material covered in class will take the lecture and turn it into practice. A small written report and corresponding code are required. A starter Matlab code will be provided as a base to build upon. If done as a group, the expectation for the work completed will scale with the number of people in that group. Please reference the associated project specific requirements for details.

## Honors credits

If you are an honors student and wish to receive honors credits for this class you must register for the honors section. Honors students registered for the honors section will be required to perform additional tasks on the project. Details may be found on the project description.

## Problem sets

Homework is regularly assigned, a full list of problem sets for the whole semester is posted on Canvas. Assignments will be regularly collected via Canvas, but only graded if you are on the borderline between grades. The solutions will be posted online and no late assignments will be collected. The due dates are listed in the table below, and each is due no later than 11:30am on the day listed. The due dates are subject to change as the semester progresses.

| Problem Set | Due Date | Problem Set | Due Date |
|---|---|---|---|
| 1 | 9/16 | 9 | Not assigned |
| 2 | 9/16 | 10 | 10/28 |
| 3 | 9/16 | 11 | 11/4 |
| 4 | 9/23 | 12 | 11/4 |
| 5 | 9/23 | 13 | 11/18 |
| 6 | 9/30 | 14 | 11/18 |
| 7 | 9/30 | 15 | 11/18 |
| 8 | 10/7 | 16 | 12/9 |

**Tentative schedule**

| WK | Class No. | Day | Topic | Pages |
|---|---|---|---|---|
| 1 | 1 | 9/4 | Intro. | - |
| 2 | 2 | 9/9 | Math review. 1D truss | Notes; Chapter 2 |
| | 3 | 9/11 | 1D & 2D truss | Chapter 2 |
| 3 | 4 | 9/16 | 1D strong and weak forms | Chapter 3 |
| | 5 | 9/18 | 1D approximations | Chapter 4 |
| 4 | 6 | 9/23 | 1D FE formulation | Chapter 5 |
| | 7 | 9/25 | 1D heat transfer | Chapter 5 |
| 5 | 8 | 9/30 | 1D linear elasticity | Chapter 5 |
| | 9 | 10/2 | 1D thermo-elasticity | Notes |
| 6 | 10 | 10/7 | 1D numerical implementation | Notes |
| | 11 | 10/9 | Review of 1D | - |
| 7 | 12 | 10/14 | **No class** (SES) | - |
| | 13 | 10/16 | **Exam 1** | - |
| 8 | 14 | 10/21 | 2D strong and weak forms | Chapter 6 |
| | 15 | 10/23 | 2D elements | Chapter 7 |
| 9 | 16 | 10/28 | 2D elements | Chapter 7 |
| | 17 | 10/30 | 2D heat transfer | Chapter 8 |
| 10 | 18 | 11/4 | 2D linear elasticity | Chapter 9 |
| | 19 | 11/6 | Beams | Chapter 10 |
| 11 | 20 | 11/11 | **No Class** (ASME) | - |
| | 21 | 11/13 | **No Class** (ASME) | - |
| 12 | 22 | 11/18 | **No Class** (RAM3) | - |
| | 23 | 11/20 | **Exam 2** (RAM3) | - |
| 13 | 24 | 11/25 | Non-linear solution methods | Notes |
| | | 11/27 | **No Class, Friday classes meet** | - |
| 14 | 25 | 12/2 | 1D non-linear heat transfer | Notes |
| | 26 | 12/4 | 1D non-linear elasticity | Notes |
| 15 | 27 | 12/9 | Matlab | Notes |
| | 28 | 12/11 | Project Q&A | - |