ME 404/504
Computational Mechanics

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Course description and objectives

The derivation of partial differential equations which describe a physical phenomenon is a relatively simple task. Finding an analytical solution which satisfies the differential equation within a given domain and a set of boundary conditions, on the other hand, is more or less impossible, except in a few simple cases. Fortunately, many numerical techniques exist for finding approximate solutions to these differential equations. Arguably the most powerful numerical technique is the finite element method (FEM), which is the topic of this course. The principal aim of the course is to provide the student with an understanding of the mathematical basis of the FEM. Because of the limited duration of the course, one-dimensional problems will be emphasized, although the extension to two-dimensional problems will also be illustrated. A good deal of independent study on the part of the student, in the form of homework and computer projects, is expected. It is hoped that the student will gain familiarity with the terminology, the mathematical background, and the application-based experience that will make it a competent user of the vast array of FEM-based analysis packages that are available.

Course structure:

Two 75 minute sessions per week (T-R 11:00 - 12:15). Each session will contain theory and example problems as appropriate.
Course assessment (tentative):

- homework: 20%
- computer projects: 30%
- mid-term test: 20%
- final test: 30%

Course outline:

1. Introduction
   • Why the FEM?
   • A brief history

2. Basic mathematics:
   • Approximate solutions
   • Weighted residuals
   • Useful theorems
   • Functionals
   • Variational symbol

3. Weak formulation of BVPs
   • Integral statement
   • Weak formulations
   • Various methods of approximate solution

4. The FEM for 1–D problems
   • Second–order problems
   • Fourth–order problems (beams)
   • Accuracy, error and convergence
   • Eigenvalue problems
   • Computer implementation

5. The FEM for 2–D problems
   • Classification of problems
   • Single variable problems
• Numerical tools
• Incompressible flow
• Introduction to transient analysis
• Introduction to vector-valued solutions