ME 418 - Finite Element Analysis in Mechanical Engineering Design

Catalog Data:	**ME418: Finite Element Analysis in Mechanical Engineering Design. 3(2,3).** Introduction to the finite element method. Introduction to solid modeling, finite element modeling and analysis using commercial codes. Analysis strategies using finite elements. Applications to heat transfer, fluid flow and structures. *Preq:* EM 304, 320, ME 205, 304, or consent of instructor.
Textbook:	David V. Hutton, Fundamentals of Finite Element Analysis, McGraw Hill, 2004.
Coordinator:	L. L. Thompson, Associate Professor of Mechanical Engineering and Engineering Mechanics

Objectives[1]:

1. To teach students the basic concepts in the finite element method (FEM) as related to solving engineering problems in solids, fluids, and heat transfer. [B,D,G]
2. To provide students with a working knowledge of computer-aided engineering analysis tools and their use in design. [D,E,F,G,J]

Pre/Co-requisites by Topic:

1. Numerical integration and differentiation. (ME 205)
2. Solution of simultaneous linear algebraic equations. (ME 205)
3. Matrix algebra. (ME 205)
4. Linear heat conduction. (ME 304)
5. Solid mechanics of beams, rods, shafts. (EM 304)
6. Potential flow, flow in pipes. (EM 320)

Topical Outline:

1. The role of finite element analysis (FEA) in the design process. (2 hours)
2. Basic concepts of the finite element method. (3 hours)
3. Illustrative Examples of solid mechanics, heat conduction. (3 hours)
4. Matrix assembly, conformability and completeness. (2 hours)
5. Variational equation. (6 hours)
6. Types and application of boundary conditions, solution of simultaneous equations. (2 hours)
7. Correct modeling practice in design assessments by FEM. (1 hour)
   Assignment and discussion of pre-design project for stress analysis. (1 hour)
8. Theory of FEM heat transfer and elasticity analysis. (4 hours)
9. Constant gradient triangle, higher order and isoparametric elements. (8 hours)
10. Discussion and assignment of predesign project for heat transfer. (1 hour)
11. Illustrative example – Potential flow of a fluid. (2 hours)
12. Assignment and discussion of thermal design project. (1 hour)
13. Beam and frame structures. (4 hours)
14. Tests. (3 hours)

Design Projects:

[1] Letters in brackets refer to the ME Program Educational Objectives.

Several design projects will be assigned. The final mechanical design project is intended to be a real-life problem selected by the student with approval of the instructor, e.g. design and analysis of a bicycle for strength, or thermal analysis of a computer chip.

Computer Usage:

Both commercial CAE codes such as I-DEAS and small instructional FEM codes written in e.g. Matlab are utilized by students in at least two pre-design projects in which students learn (1) modeling practices necessary to obtain reliable results and (2) the proper role of FEA in the overall design process. One open-ended mechanical design project is assigned. Computational work will be performed using graphical workstations.

Evaluation Methods:

1. Homework = 10%
2. Design/Computer Projects = 25%
3. Tests = 40%
4. Final Exam = 25%
5. Laboratory Reports = 0%

Student Learning Outcomes[2]:

Course Objective 1

1. Students will demonstrate a basic understanding of FEA applied to heat transfer, fluid mechanics and solids and structures. [1,2,3,4]
2. Students will demonstrate the use of element approximations using shape functions to formulate element matrices and load vectors, and direct assembly to form the global matrix problem. Ability to apply boundary conditions and solve for nodal solution variables. Ability to post-process data to obtain secondary parameters such as stress and heat flux. [1,3]

Course Objective 2

1. Students will demonstrate ability to use FEA to perform parametric studies to optimally design structures for failure, and to design devices with desired heat flow behavior. [2,4]
2. Students will demonstrate ability to simplify design based on solid CAD model for analysis using efficient finite element meshes, and the proper selection of elements, for example when to use solid elements versus shell elements. [2,4]
3. Students will demonstrate ability to decide when the finite element approximation is sufficient for an accurate solution based on mesh convergence studies and monitoring stress and heat flux gradients. [1,2,3,4]

Course Objective 3

1. Students will demonstrate the ability to give a professional and well organized presentation of their design and analysis through the use of written and optional oral reports. [2,4]

Engineering Topics:

Engineering Science: 2 credits
Engineering Design: 1 credit

Prepared by: L. L. Thompson

[2] Numbers in brackets refer to evaluation methods to assess student performance.