The Hong Kong University of Science and Technology

UG Course Syllabus

Course Title: Introduction to Finite Element Analysis
Course Code: MECH 4450
Number of Credits: 3
Pre-Requisites: MECH 2040

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Office Hours: By email appointments

Course Description

Basic concepts of finite element methods (FEM), element equations for basic structural elements, implementation and application of FEMs in 1-D and 2-D structural analysis and heat conduction.

Textbook & Material

- Instructor Notes
- T. R. Chandrupatla, A. D. Belegundu, Introduction to Finite Elements in Engineering, Third Edition, Pearson Education, New Jersey, 2002.
- Moaveni, Finite Element Analysis: Theory and Applications with ANSYS, Second Edition, Pearson Education, New Jersey, 2003.

Course Topics

- Introduction
- Review of basic numerical methods
- Finite element analysis of 1-D problems
    - Axially loaded bar
    - Heat conduction
    - Truss structure
    - Bending beam and frame
- ANAYS tutorial
- Finite element analysis of 2-D problems
    - Heat conduction
    - Plane stress/strain
- Advanced topics
    - 3-D elasticity
    - Mode analysis
    - Nonlinear problems

Course Objectives

- To teach students the basic principles of finite element methods.
- To teach students the basic implementation method of finite element methods.
- To teach students how to perform 1-D and 2-D structural analysis and heat conduction using finite element methods.
- To teach students how to design structures using commercial software package ANSYS.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Have a basic understanding of the principles and concepts related to finite element methods.
2. Implement finite element methods for simple 1-D problems such as truss analysis and 1-D heat conduction either by hand calculation and by programming.
3. Numerically solve for stresses, strains and deformation of a structural component due to axial load, torsion, and bending, acting individually or in combination.
4. Numerically solve for temperature profile and heat flux in 1-D and 2-D heat conduction problems.
5. Numerically solve for stresses, strains and deformation of a structure under either plane-stress or plane-strain conditions.
6. Have a basic knowledge about finite element methods for solving time-dependent and/or non-linear problems.
7. Use commercial software package to perform structural analysis and heat transfer modeling, and are able to conduct engineering design in a team work environment.

Assessment and Grading

This course will be assessed using criterion-referencing. Detailed rubrics for each assessment task are provided below.

- **Homework:** Regular problem sets designed to reinforce concepts and analytical analysis.
- **Midterm Exam:** Formative evaluation of understanding of concepts, principles and implementation scheme of finite element methods.
- **Term Project:** Comprehensive assessment evaluating method implementation, FEM analysis and design skills of mechanical systems.

Assessment Task	**Contribution to Overall Course Grade (%)**	**Assessment/Due Date**
Homework	20%	End of each topic
Midterm Exam	40%	End of 1-D problems
Term project	40%	Before final examination period

Mapping of Course ILOs to Assessment Tasks

Assessment Task	Mapped ILOs	Explanation PDF
Homework	ILO 1, 2, 3, 4, 5, 6, 7	Regular problem sets assess students' ongoing understanding about FEM principles and capabilities of FEM implementation across all covered syllabus topics.
Midterm Exam	ILO 1, 2, 3, 4	Formatively evaluates conceptual understanding and calculation skills regarding FEM principles and implementation related to 1D problems.
Term project	ILO 1, 2, 3, 4, 5, 6, 7	Evaluates comprehensive mastery of: (1) FEM and numerical analysis; (2) structural analysis and heat conduction; and (3) mechanical system design.

Grading Rubrics

The following rubrics describe the general criteria used to assess the major assessment components in this course. More detailed task-specific marking schemes may be provided for individual homework assignments and examination questions.

Rubric for Homework Assignments and Midterm Exam

Criteria	Excellent	Good	Satisfactory	Marginal	Fail
Conceptual understanding and model construction	Demonstrates clear and accurate understanding about principles of FEM. Able to construct FEM models and shape functions accurately.	Shows good understanding of FEM principles. Able to construct FEM models and shape functions with only minor omissions or imprecision.	Shows adequate understanding of FEM principles, but may lack depth. Able to construct FEM models and shape functions but with some errors.	Shows limited understanding of FEM principles, with noticeable gaps in core concepts. Attempts to construct FEM models and shape functions but makes frequent or significant errors that affect basic functionality.	Shows insufficient or no understanding of FEM principles. Unable to construct FEM models or shape functions correctly, or makes no meaningful attempt.
Implementation of FEM	Demonstrate accurate implementation of FEM methods in 1-D and 2-D structural analysis and	Demonstrates mostly accurate implementation of FEM methods in 1-D and 2-D structural analysis and heat	Shows adequate implementation of FEM methods in 1-D and 2-D structural analysis and heat	Shows limited implementation of FEM methods, with significant errors in 1-D or 2-D problems, or weak application to	Shows no meaningful implementation of FEM methods; unable to correctly solve 1-D or 2-D problems in

	heat conduction.	conduction, with only minor errors.	conduction, but with some errors that may affect accuracy.	structural analysis or heat conduction.	structural analysis or heat conduction.

Rubric for Team Project

Criteria	Excellent	Good	Satisfactory	Marginal	Fail
Problem understanding and Conceptual design	Clearly and thoroughly describes the problem, design objectives, and constraints. Presents an innovative, well-reasoned conceptual design with clear diagrams. Demonstrates excellent attention to aesthetics and practicability.	Clearly describes the problem, objectives, and constraints. Presents a sound conceptual design with diagrams. Shows good consideration of aesthetics and practicability.	Adequately describes the problem, objectives, and constraints. Presents a basic conceptual design with some diagrams. Shows some consideration of aesthetics or practicability, but may lack depth.	Provides limited or unclear description of the problem or objectives. Conceptual design is vague, incomplete, or lacks diagrams. Little consideration of aesthetics or practicability.	Fails to describe the problem or objectives meaningfully. No coherent conceptual design or diagrams provided. No consideration of aesthetics or practicability.
Detailed design and FEM analysis	Provides complete, precise detailed design. Demonstrates accurate FEM implementation in structural and/or thermal analysis. Mesh, element types, loading conditions, results, and convergence study are thorough and correct. Results are clearly interpreted and linked to design decisions.	Provides mostly complete detailed design with minor omissions. Demonstrates generally accurate FEM analysis with only minor errors. Mesh, element types, loading conditions, and convergence study are mostly correct. Results are clearly presented.	Provides adequate detailed design but with some missing details or errors. Demonstrates adequate FEM analysis with some errors that may affect accuracy. Mesh, element types, or loading conditions have minor issues. Convergence study is attempted but incomplete. Results are presented but interpretatio	Provides incomplete or vague detailed design with significant gaps. Demonstrates limited FEM analysis with frequent or significant errors. Mesh, element types, or loading conditions are poorly defined. Convergence study is missing or flawed. Results are poorly presented or interpreted.	Provides no meaningful detailed design. Demonstrates no meaningful FEM analysis, or analysis is completely incorrect. Mesh, element types, loading conditions, and results are absent or nonsensical. No convergence study attempted.

			n may be shallow.		
Performance analysis and optimization	Provides accurate, thorough cost estimation and performance evaluation. Optimization approach is well-designed, systematic, and effectively improves the design. Final design demonstrates clear trade-off analysis between performance and cost.	Provides mostly accurate cost estimation and performance evaluation. Optimization approach is sound and leads to reasonable design improvements. Trade-off analysis is present but may lack depth.	Provides adequate cost estimation and performance evaluation, but with some errors or omissions. Optimization approach is basic but attempted. Design improvements are modest or not fully justified.	Provides limited or inaccurate cost estimation or performance evaluation. Optimization approach is weak, poorly executed, or missing key steps. Design shows little or no improvement.	Provides no meaningful cost estimation, performance evaluation, or optimization. No attempt to improve the design.
Report	Summary clearly and concisely synthesizes key findings, conclusions, and recommendations. Report is exceptionally well-organized, with excellent grammar, formatting, and professional presentation.	Summary clearly presents key conclusions. Report is well-organized with good grammar and formatting. Minor issues only.	Summary presents basic conclusions but may lack synthesis or clarity. Report is adequately organized but has some grammatical, formatting, or clarity issues.	Summary is vague, incomplete, or unclear. Report is poorly organized or has frequent grammatical/formatting issues that affect readability.	No meaningful summary or conclusions. Report is disorganized, unprofessional, or largely incomprehensible.
Presentation	Presentation is clear, well-structured, and engaging. Visual aids (slides, diagrams) are professional and effective. Time management is excellent. Answers questions confidently and accurately.	Presentation is clear and well-structured. Visual aids are good. Time management is good. Answers questions correctly with minor hesitation.	Presentation is adequate but may lack polish or clarity. Visual aids are acceptable but could be improved. Time management is acceptable. Answers questions adequately but with some difficulty.	Presentation is unclear, disorganized, or too short/long. Visual aids are poor or missing. Time management is poor. Struggles to answer questions correctly.	No meaningful presentation, or presentation is completely incoherent. No visual aids. Unable to answer questions.

Final Grade Descriptors

Grades	Elaboration on Subject Grading Description	Short Description
A	Demonstrates clear and accurate understanding of FEM principles. Accurately implements FEM methods in 1-D and 2-D structural analysis and heat conduction. Accurately applies ANSYS to conduct structural and heat conduction analysis and designs high-performance mechanical structures and systems. Exhibits exceptional problem-solving and analytical skills across all topics.	Excellent Performance
B	Shows good understanding of FEM principles, with only minor omissions or imprecision. Demonstrates mostly accurate implementation of FEM methods in 1-D and 2-D problems, with only minor errors. Applies ANSYS with general accuracy and designs good-performance mechanical structures and systems.	Good Performance
C	Shows adequate understanding of FEM principles, but may lack depth. Able to construct FEM models and shape functions with some errors. Shows adequate implementation of FEM methods in 1-D and 2-D analysis, though with some errors that may affect accuracy. Applies ANSYS to basic analysis and designs acceptable-performance mechanical structures and systems.	Satisfactory Performance
D	Shows limited understanding of FEM principles, with noticeable gaps in core concepts. Attempts to construct FEM models and shape functions but makes frequent or significant errors affecting basic functionality. Shows limited implementation of FEM methods with significant errors in 1-D or 2-D problems, or weak application to structural analysis or heat conduction. Able to produce only basic or low-performance mechanical designs using ANSYS.	Marginal Pass
F	Shows insufficient or no understanding of FEM principles. Unable to construct FEM models or shape functions correctly, or makes no meaningful attempt. Shows no meaningful implementation of FEM methods; unable to correctly solve 1-D or 2-D problems in structural analysis or heat conduction. Unable to apply ANSYS correctly or design functional mechanical structures and systems.	Fail

Communication and Feedback
Assessment marks for individual assessed tasks will be communicated via Canvas within two weeks of submission. Solutions to homework problems will be provided after the submission deadline. Students who have further questions about the feedback including marks should consult the instructor or teaching assistants after the feedback is received.

Late Homework Submission Policy
Late submissions are not permitted. Requests for deadline postponement must be made in advance, preferably at least one week prior, for example, in cases of heavy workloads or multiple exams, to allow proper arrangements. For sickness or emergencies, official documentation is required.

Course AI Policy
The use of Generative AI is prohibited for solving homework problems, answering the midterm exam, and executing the technical components of the term project. Generative AI tools may be utilized as supplementary learning aids, or to assist with outlining and improving the grammar and structure of the term project report.

Academic Integrity
Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST's Academic Honor Code and to maintain the highest standards of academic integrity. The University has zero tolerance of academic misconduct. Please refer to Academic Integrity | HKUST - Academic Registry for the University's definition of plagiarism and ways to avoid cheating and plagiarism.