Finite Element Analysis
ME 477/677 Spring 2024

Instructor Dr. Xinnan Wang (E-mail: xinnan.wang@ndsu.edu)
Office Hours: Shown on BB (under Contacts tab)

Lecture/Lab MW: 3– 4:50 pm, AGHILL 234 (Default) OR AGHILL 240

Reference Book:

- A First Course in the Finite Element Method, 6th Ed., Daryl L. Logan, Cengage learning, 2016.
- Finite Element Simulations with ANSYS Workbench 18, Huei-Huang Lee, SDC Publications, 2018.

Course Description

This course introduces the theory and application of the finite element method, with an emphasis on the ***use*** of the method. The course is divided into two parts: a discussion of the concepts and theory behind the FE method, and the use and application of the method using the commercial software package ANSYS Workbench. The theory and application will be presented concurrently throughout the semester. Topics will include 2D and 3D stress analysis (linear and nonlinear), thermal analysis, beam and frame analysis, modeling techniques, and critiquing the results.

Grading

Undergraduate		Graduate	
Homework Problems:	20%	Homework Problems:	20%
ANSYS Assignments:	35%	ANSYS Assignments:	35%
Design Project (ANSYS):	10%	**Research** Project (ANSYS):	15%
1 midterm & Final Exam:	35%*	1 midterm & Final Exam:	30%*

*: Each test and final exam are equal weight.

Homework Problems

Traditional homework problems focusing on the theory will be assigned periodically. These problems may include derivations and analytical problems requiring hand computations. Due time for HWs will be a week after they are assigned on BlackBoard. No late HW is accepted without special permission from the instructor.

ANSYS Assignments

Roughly 7-9 ANSYS assignments will be given throughout the semester. These project assignments are to be done individually. No late ANSYS assignment is accepted without special permission from the instructor.

Group Design Project/Graduate Research Project

A group design project will be required by the end of the semester. This project will be conceived by the group, must be of a "design" nature (no unique answer will exist), and will require the use of ANSYS (with more than one iteration). Groups of 3-4 people will work on the project. A final report must be submitted detailing the project introduction, objectives, constraints, modeling techniques and assumptions, results and discussion of the project. In place

of a design project, graduate students are required to individually complete a research-oriented project that uses advanced capabilities of ANSYS.

Exams

Two exams (midterm and final) will be given. The exams cover the theoretical material, general modeling techniques, etc. as discussed in lectures, but do not specifically cover the use of ANSYS.

Course Evaluation

90 - 100%	A
80 - 89.9%	B
70 - 79.9%	C
60 - 69.9%	D
Less than 60%	F

Course Outcomes

1. Students must understand the basic formulations used in the development of the finite element method.
2. Students must be able to construct, analyze, and interpret the results of a finite element model using commercially available software (e.g., ANSYS).
3. Students must have an understanding of the different element types available, and select appropriate elements for a particular type of analysis.
4. Students must have an understanding of the methods by which a model can be constrained and loaded, and be able to apply loads and constraints to a finite element model that reasonably represent the loads/constraints applied to the physical structure.
5. Students must have an understanding of the sources of error in a finite element model (e.g., mesh discretization error, numerical error, etc.), and apply techniques to reduce the potential for error in modeling.
6. Students must be able to analyze two and three-dimensional structural problems using FE software.
7. Students must be able to use FE software as a tool in the iterative design process.

Program Outcomes

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Communication

- The primary method by which course-related information will be communicated is in-class instruction. Reminders, notification of any schedule or assignment changes will be communicated through NDSU email and/or posted on Blackboard announcements page.
- Your NDSU email address is the official route for information.

Instructor Expectation

- Students are strongly suggested to allocate enough hours to review the materials after each class and finish related homework. Pre-reading before each class also improve understanding of the materials.
- Students are responsible for the materials that are covered in the class.

Health and Safety Expectations

NDSU requires masks to be worn in all classroom settings. **In this class all participants, including those who are fully vaccinated, are required to wear a face covering.** If you fail to properly wear a face covering, you will not be admitted to the classroom. The following will be used as needed: referral to Dean of Students Office or administrative removal from class.

- Students who cannot wear a face covering due to a medical condition or disability, or who are unable to remove a mask without assistance may seek an accommodation through the Disability Services (701-231-8463; https://www.ndsu.edu/disabilityservices/).
- In accordance with NDSU Policy 601, failure to comply with instructions, including the mask requirement, may be handled according to the Code of Student Conduct resolution process and may result in disciplinary sanctions.
- Food and drink are not allowed in the class unless a student has a documented accommodation through Disability Services. Students will have to remove their masks to eat or drink.

Attendance Statement

- According to NDSU Policy 333 (www.ndsu.edu/fileadmin/policy/333.pdf), students are expected to attend every class and remain in class for the duration of the session when it is safe to do so in accordance with NDSU guidance regarding COVID-19.
- In this course students should participate in the course face-to-face.
- Please note that instructors will be flexible regarding deadlines for students who are experiencing illness or other challenges related to COVID-19. Please contact your instructor as early as possible with proof if you think you may not be able to complete an assignment or participate in the course due to illness.

Academic Honesty Statement

The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students

found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

Americans With Disabilities Act For Students With Special Needs

Any students with disabilities or other special needs, who need special accommodations in this course, are invited to share these concerns or requests with the instructor and contact the Disability Services Office (www.ndsu.edu/disabilityservices) as soon as possible.

Veterans

Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.

Copyright of Course Materials

Refer to NDSU Policy 190 on Intellectual property.

- In this course recording the lectures is prohibited with your own personal devices.

Additional Resources for Students

Students are encouraged to use support resources

- As a member of the NDSU community, resources are available for you should you need help in dealing with adverse reactions to things happening in the world today. A variety of resources are listed below:
  For students on campus and remotely (telehealth):
  Counseling Services: 701-231-7671; https://www.ndsu.edu/counseling/
  Disability Services: 701-231-8463; https://www.ndsu.edu/disabilityservices/
  Student Health Service: 701-231-7331; https://www.ndsu.edu/studenthealthservice/
  Dean of Students Office: 701-231-7701; https://www.ndsu.edu/deanofstudents/
  In a crisis or emergency situation:
  Call University Police: 701-231-8998
  Call 9-1-1
  Go to a Hospital Emergency Room
  Go to Prairie St. Johns for a Needs Assessment: 701-476-7216 (510 4th St. S.)
  Call the FirstLink Help Line: 1-800-273- TALK (8255) or 2-1-1
  Call Rape and Abuse Crisis Center: 701-293-7273

Tentative Course Outline (subject to change)

Topic

Introduction to the Finite Element Method
Background, history, classification of methods, steps, applications

Direct Stiffness Method Using Spring Elements
Stiffness matrix, spring elements, superposition, boundary conditions, minimum potential energy approach

Truss (Bar) Elements

Basic formulation, interpolation functions, 2D transformation, global stiffness matrix stress calculations, 2D and 3D trusses, symmetry,

2D Stress Analysis Problems
Plane stress and plane strain, constant-strain triangle (CST) element, linear-strain triangle (LST) element, body and surface forces, failure (yield) criteria

Frames
2D beam transformation, planar frames, 3D beams

ANSYS Workbench
Introduction, sketching, 2D stress analysis problems

Modeling Considerations
Element shape, symmetry, mesh sizing and refinement, loads and boundary conditions, equilibrium and compatibility, convergence of solution

Heat Transfer Problems
Basic formulation (steady-state), conduction and convection, 1D, 2D formulations, Transient (time-dependent) heat-transfer problems

Isoparametric Formulation
Bar elements, rectangular plane stress elements, Gaussian and Newton-Cotes quadrature

3D Stress Analysis Problems
Stress-strain relations, tetrahedral elements, hexahedron elements, isoparametric formulation

ANSYS Workbench
3D solid modeling, 3D stress analysis problems

Beam Elements
Basic formulation, direct stiffness method, distributed loads, 2D beam transformation, planar frames, 3D beams

ANSYS Workbench
3D line models (beam elements)

ANSYS Workbench
Surface models (shell elements)

Nonlinear Problems (Structural)
Material vs. geometric nonlinearities, solution methods, material behavior, contact problems

Important Dates

FOR DETAILED INFORMATION, CHECK:
https://www.ndsu.edu/onestop/academic-calendar