MFG 512 Mechanics of Solids

Instructor	Adnan Kefal (*adnankefal@sabanciuniv.edu*)
Course Attributes	Sabanci University – 2024-25 Fall Semester Doctorate/Master Level 3 SU Credit / 10 ECTS / 42 Teaching Hours
Course Schedule	Mon 09:40 - 10:30 FASS 1102 Wed 08:40 - 10:30 FENS G015
Course Prerequisite	A foundational understanding of *Strength of Materials* is required for this course. This includes familiarity with basic concepts like stress, strain, and elasticity, as well as proficiency in mathematical techniques used in engineering mechanics, e.g., linear algebra, vector/matrix operations.

Content & Objectives

This course is primarily designed for graduate students to gain understanding in the fields of mechanics of solids. The course introduces concepts of continuum mechanics, thermodynamic laws, and governing physics and equations for deformation of solids based on small and large deformation theories. The finite element concepts will be explained at introductory level and the students will be asked to solve practical solid mechanics problems using both analytical/numerical methods.

Learning Outcomes

1) Vector calculus and mathematical background for solid mechanics
2) Understanding of small/large deformation theories
3) Understanding of constitutive relations and internal forces
4) Ability to develop variational methods for solid mechanics
5) Understanding of analytical solutions for boundary value problems
6) Finite element skills with applications of 1D-2D problems

Syllabus

Week	Topic
Lecture 1-2	**Introduction to Vector/Tensor Calculus** Scalars, vector and tensor definition, index (Summation) notation, vector/tensor operations, cross product, dyadic product, inner product, double contractions, transpose, Kronecker delta and Levi-Civita operators, high-order tensors, Eulerian/Lagrangian description, spatial derivatives including gradient, divergence, curl.
Lectures 3-4	**Deformation and Shape Changes in Solids** Reference/deformed configurations, displacement and deformation gradient tensors, Jacobian of the deformation gradient, Lagrange/Euler strain tensors, infinitesimal strain/rotation tensors, Cauchy-Green deformation tensor transformations.
Lecture 5-6	**Internal Forces in Solids** Surface tractions, internal body force, traction acting on planes, Cauchy stress tensor, stress conjugates, Kirchhoff, nominal, and material stress tensors, hydrostatic, deviatoric, von Mises effective stresses, 1st/2nd Piola-Kirchhoff Stress Tensors, boundary conditions on stresses.

Lectures 7-8 **(Midterm1)**	**Constitutive Equations** Symmetry property of elasticity tensor, isotropic elasticity tensor bulk, shear and Lame constants, Young's modulus, Poisson's ratio, thermal expansion coefficients, orthotropic elasticity tensor, transversely isotropic materials, anisotropic elasticity tensor, reduced stress-strain equations for plane deformation of isotropic solids, strain energy derivation of elasticity.
Lecture 9	**Thermodynamic Laws and Equilibrium Equations** Thermodynamic states and restrictions, equation of motion for deformable bodies, linear momentum balance in terms of Cauchy stress, angular momentum balance in terms of Cauchy stress.
Lecture 10-11	**Variational Methods and Principal of Virtual Work and Energy** Work done by Cauchy stresses, rate of mechanical work in terms of stress measures and infinitesimal deformations, virtual work equations in terms of stress measures and infinitesimal deformations, Rayleigh-Ritz method, Reissner's variational theorem, weighted residual methods.
Lecture 12	**Solutions for Linear Elastic Solids and Boundary Value Problems** Summary of governing equations: boundary and initial boundary value equations, superposition and linearity of solutions, uniqueness and existence of solutions, Airy function solution to plane stress and strain static linear elastic solids, variational derivations of beam equations.
Lectures 13-14 **(Midterm2)**	**Finite Element Method and Computational Applications** Finite element mesh, element types, material behavior, boundary conditions, solution procedures and time increments, post-processing, 1D/2D applications of finite element method.

References

1. Bower, A.F., 2009. Applied mechanics of solids. CRC press.
2. Logan, D.L., 2016. A first course in the finite element method. Cengage Learning.
3. Zienkiewicz, O.C., Taylor, R.L., Taylor, R.L. and Taylor, R.L., 2000. The finite element method: solid mechanics (Vol. 2). Butterworth-heinemann.
4. Reddy, J.N., 2003. Mechanics of laminated composite plates and shells: theory and analysis. CRC press.

Assessment Criteria

Midterm Exams (2×30%), Final Exam (40%)

Course Material

The outline of lecture notes, project guidelines, and other course-related material will be posted at the SUCourse site *(https://sucourse.sabanciuniv.edu/)*.