Instructors: Yasemin Sengul TezelEralp DemirEmail: yaseminsengul@sabanciuniv.edueralpd@sabanciuniv.eduClass hours/place:

Office Hours: After class, or by appointment

Main References:

- Allan F. Bower, Applied Mechanics of Solids, CRC Press, 2009.
- Robert M. Jones, Mechanics of composite materials, CRC Press, 1998.
- Fionn Dunne, Nik Petrinic Introduction to Computational Plasticity, Oxford University Press, 2006.
- Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J.Witt, *Concepts and Applications of Finite Element Analysis*, John Wiley & Sons Inc., 2002.

Objectives: This course is primarily designed for graduate students to gain understanding in the field of mechanics of solids. Course introduces concepts of continuum mechanics and governing physics of deformation of solids including large deformation theory. The finite element concepts will be explained at introductory level and the students will be asked to solve practical solid mechanics problems using a commercially available finite element software.

Prerequisites: -

Tentative Course Outline:

Week-1: Objectives and Applications of Solid Mechanics

Basic introduction of equilibrium equations, finite element applications, examples

Week-2: Review of Engineering Mechanics

Review of Engineering level Mechanics background: stress-strain relations, tension, compression, bending, torsion, complicated loading, beam deflections and buckling

Week-3: Introduction to Vector & Tensor Algebra

Vector and Tensor definition, Index (Summation) notation; Tensor operations; cross product, dyadic product, inner product, double contractions, transpose etc.; Kronecker Delta, Levi-Civita operators; 2nd, 3rd and 4th order tensors; Description of Physical Quantities (Eulerian or Lagrangian); Spatial derivatives: gradient, divergence, curl

Week-4: Deformation and Strain Measures

Reference and deformed configurations; Displacement and velocity fields; Displacement gradient and deformation gradient tensors; Jacobian of the deformation gradient; Lagrange strain tensor; Infinitesimal strain tensor; Engineering shear and normal strains; Decomposition of infinitesimal strain into volumetric and deviatoric parts; Infinitesimal rotation tensor; Principal values and directions of the infinitesimal strain tensor; Cauchy-Green deformation tensors; Principal stretches

Week-5: <u>Alternate Stress Measures</u>

Surface traction and body force; Traction acting on planes within a solid; Cauchy (true) stress tensor; Volume Mapping: Jacobian; Area Mapping: Nanson's relation; Other stress measures: Kirckhoff, 1st

Piola-Kirchoff, 2nd Piola-Kirckoff Stress Tensors; Nominal and Material Stress Tensors; Principal stresses and directions; Hydrostatic and Deviatoric stresses, and Von Mises stress

Week-6: Equations of motion and equilibrium for deformable solids

Linear momentum balance in terms of Cauchy stress; Angular momentum balance in terms of Cauchy stress; Equations of motion in terms of other stress measures; Principal of virtual work

Week-7: Constitutive Equations: Relations between Stress and Strain

Strain energy derivation of elasticity; Symmetry property of elasticity tensor; Isotropic elasticity tensor bulk, shear and Lame constants; Ortho-tropic elasticity tensor

Week-8-9: Composite Laminate Mechanics

Plate deformation theory, Laminae micro mechanical elastic properties; Laminate macro mechanical elastic properties; Transformation rules for elastic modulus; Stress-Strain relations for laminate (ply mechanics) Week-10: Isotropic Plasticity (An Introduction)

Strain Decomposition; In-compressibility Condition; Effective stress and plastic strain rate; Yield Criterion; Normality Rule; Implicit Integration of Constitutive Equations; Material Jacobian **Week-11-12**: Crystal Plasticity

Anisotropic Elasticity; Schmid-Rule (Sachs); Taylor Rule; Rate-Dependent Plastic Flow; Crystal Plasticity Deformation Kinematics; Single Crystal Phenomenological and Dislocation Density based plastic flow rules; Implicit Integration of Crystal Plasticity

Week-13: A Guide to Use a Finite Element Software

Finite element mesh; Nodes and Elements; Element Connectivity; Element Types; Material Behavior; Boundary conditions; Initial conditions; Constraints; Solution Procedures and Time Increments; Post-Processing

Week-14-15 Theory and Implementation of the Finite Element Method

Generalized FEA for static linear elasticity; Review of the principle of virtual work; Integral (weak) form of the governing equations of linear elasticity; Interpolation of displacement field and virtual velocity field; Finite element equations; Element Stiffness; Simple 1D Implementation of the finite element method; Summary of the 1D finite element procedure; Example FEM Code structure: mesh and material inputs, processor, assembly of equations, solution procedures etc.

Learning Outcomes:

- Mathematical background for solid mechanics problems
- Understanding of large deformation theory
- Ability to develop continuum elastic models for solid mechanics problems
- Understanding and application of composite ply mechanics
- Introductory level understanding of plasticity: isotropic plasticity and crystal plasticity
- Finite element skills with applications of 1D problems
- Ability to solve basic engineering problems with the use of a commercially available software

Computer Programming: Matlab, Fortran, MSC-MARC

Grading Policy: Assignments(30%), Project (10%), Midterm (25%), Final (35%).

Important Dates:

will be announced

Class Policy:

• Regular attendance is essential and expected.