ME __5XX____
Solid Mechanics II

Course Outcomes

1. Select the most appropriate theory for modeling a particular material and structure in a given application, and outline the variables and general parameters needed, as well as the limitations of the chosen theory. [1, 2, 7]
2. Comprehend the response of nonlinear elastic materials (hyperelasticity), rate-dependent materials (viscoelasticity), and path-dependent materials (plasticity), and the corresponding material properties involved in their characterization. Specific outcomes are defined by the instructor. [1, 2, 7]
3. Comprehend the formulation of structural elements (beams, plates, shells) as the analytical upscaling of continuum solids under kinematic assumptions. Specific outcomes are defined by the instructor. [1, 2, 7]
4. Comprehend the formulation of solid-solid and solid-fluid interactions as the analytical upscaling of continuum solids under kinematic assumptions and specific boundary conditions. Specific outcomes are defined by the instructor. [1, 2, 7]
5. Develop the skill to analyze problems in mechanics of materials, interpret technical literature, and write technical report about a problem in this field. [1,2,3]

1. Review of Elasticity (2 wks)

1. Course introduction.
2. Kinematics for large deformation.
3. Conservation and balance laws.
4. Cauchy stress and other definitions.
5. Constitutive relationships.

2. Hyperelasticity (2-3 wks)

1. Strain energy density.
2. Objectivity. Material-frame indifference, Isotropy and anisotropic elastic solids.
3. Hyperelastic and incompressible solids.
4. Examples: soft tissues, polymers.

3. Viscoelasticity (1-3 wks)

1. Linear viscoelasticity (relaxation, creep)
2. Constitutive equations in integral and differential forms.
3. Maxell and Voigt models, three-dimensional constitutive models.
4. Nonlinear models.
5. Examples: soft tissues, polymers.

4. Plasticity (2-3 wks)

1. Phenomenological observations.
2. Rate independent plasticity.
3. Additive decomposition of incremental strains. Multiplicative decomposition of deformation gradient.
4. Yield criteria, flow rules, hardening rules.
5. J2 or von Mises, Mohr-Coulomb, and Drucker-Prager plasticity models.
6. Examples.

5. Structural Elements and Structural Instabilities (1-3 wks)

1. Beam, plates and shells.
2. Displacement field and constitutive relationships of elastic structures (internal resultants and kinematic variables).
3. Structural instabilities. Buckling.
4. Examples: instabilities in columns, cylindrical shells, thin films on elastic foundations (among others).

6. Solid-Solid and Fluid-Solid Interactions (2-3 wks)

1. Contact between smooth non-conforming surfaces of deformable solids.
2. Elastic, strain-rate dependent, and plastic spherical solids in contact.
3. Indentation problems (interaction between rigid and deformable solids)
4. Boundary conditions at fluid-solid interfaces. Fluid flow equations.

COURSE NUMBER: ME _5XX_____ **COURSE TITLE:** Solid Mechanics II

REQUIRED COURSE OR ELECTIVE COURSE: Elective

TERMS OFFERED: Spring

TEXTBOOK/REQUIRED MATERIAL: None, but several references will be recommended

- Elasticity: Theory, Applications, and Numerics. 4th Edition. Sadd M.H. Elsevier, 2010.
- Nonlinear Solid Mechanics. Holzapfel. Wiley, 2000.
- Continuum Mechanics and Thermodynamics. Tadmor E.B., Miller R.E., Elliot R.S. Cambridge University Press, 2012.
- Creep and Relaxation of Nonlinear Viscoelastic Materials. Findley W.N., Lai J.S., Onaran K. Dover Publications, 1989.
- The Theory of Viscoelasticity. Christensen R.M. Dover Publications, 2003.
- Contact Mechanics, Johson K.L. Cambridge University Press, 2012.
- Beams, plates, and shells. Donnell L.H. McGraw-Hill Book Co, 1976.
- Computational Inelasticity. Simo J.C. and Hughes T.J.R. Springer, 1998.

PRE-REQUISITES: Graduate student standing, Second Semester Senior Standing, Solid Mechanics I

COORDINATING FACULTY: Solid Mechanics Area Faculty

COURSE DESCRIPTION: The design of modern engineering structures is intrinsically linked to the understanding and analysis of materials and structures. This course is a foundational course on graduate level knowledge in this area of engineering.

COURSE OUTCOMES:

1. Select the most appropriate theory for modeling a particular material and structure in a given application and outline the variables and general parameters needed, as well as limitations of the chosen theory. [1, 2, 7]
2. Depending on instructor, more advanced outcomes are expected in particular subjects, for example [1, 2, 7]:
   - Formulate and evaluate the stress-strain response of a (i) hyperelastic material, (ii) a viscoelastic material, (iii) a plastic material.
   - Formulate and evaluate the internal resultant versus kinematic variable response of (i) beams, (ii) plates, and (iii) shells.
   - Formulate and evaluate the contact force (pressure) between (i) smooth non-conforming deformable surfaces (e.g., spherical objects), (ii) a rigid object on a deformable substrate (e.g., indentation), (iii) fluid-solid interfaces, for elastic solids (and/or rate-dependent solids and/or plastic solids).
3. Use solid mechanics principles to interpret and analyze the mechanical behavior of advanced engineering structures. [1,2,3,7]

ASSESSMENTS TOOLS:

1. Biweekly homework.
2. One 2-hour mid-term exam.
3. Final project.

RELATED ME PROGRAM OUTCOMES:

1. Engineering fundamentals
2. Engineering design
3. Communication skills
4. Ethical/Prof. responsibilities
5. Teamwork skills
6. Experimental skills
7. Knowledge acquisition

PROFESSIONAL COMPONENT:

1. Engineering Topics: Engineering Science – 3 credits (100%)

NATURE OF DESIGN CONTENT: Comprehend on how to realize engineering systems by use of analysis tools in advanced solid mechanics

COMPUTER USAGE: Students are expected to appropriately choose from spreadsheets, symbolic math packages.

COURSE STRUCTURE/SCHEDULE:

1. Lecture – 2 days per week at 75 minutes.

PREPARED BY: Solid Mechanics Area Faculty **REVISION DATE:** September, 2021