ME 333C - Mechanics/Continuum Mechanics

Tue/Thu 11:00-12:15, McCullough 122

Ellen Kuhl (ekuhl@stanford.edu)
Mona Eskandari (eskandar@stanford.edu)
Adrian Buganza Tepole (abuganza@stanford.edu)

Introduction to linear and nonlinear continuum mechanics of solids; Introduction to tensor algebra and tensor analysis; Kinematics of motion; Balance equations of mass, linear and angular momentum, energy, and entropy; Constitutive equations of isotropic and anisotropic hyperelastic solids; Introduction to numerical solution techniques.

Although the basic concepts of continuum mechanics have been established more than five decades ago, the 21st century faces many new and exciting potential applications of continuum mechanics that go way beyond the standard classical theory. When applying continuum mechanics to these challenging new phenomena, it is important to understand the main three ingredients of continuum mechanics: the kinematic equations, the balance equations and the constitutive equations. After a brief revision of the relevant equations in tensor algebra and analysis, this class will introduce the basic concepts of finite strain kinematics. We will then discuss the balance equations for mass, linear and angular momentum, energy, and entropy. While all these equations are general and valid for any kind of material, the last set of equations, the constitutive equations, specifies particular subclasses of materials.

Grading

Homework	30 %	three homework assignments, 10% each
Final	50 %	closed book, closed notes, one single page cheat sheet
Final Project	20 %	written evaluation of a manuscript and its discussion in class

Tue 03/31 **Motivation - Why continuum mechanics?**

Kinematics, balance principles, constitutive equations
Inhomogeneity
Nonlinearity
Inelasticity

Thu 04/02 **Introduction to vectors and tensors - Tensor algebra**
Chapter 1.1-1.5, pages 1-32

Vector algebra
Tensor algebra
Special tensors
Eigenvalues and eigenvectors

Tue 04/07 **Introduction to vectors and tensors - Tensor analysis**
Chapter 1.6-1.9, pages 32-55

Tensor analysis
Scalar, vector, tensor functions
Gradient and divergence
Integral theorems

Thu 04/09 **Kinematics I - Motion**
Chapter 2.1-2.3, pages 55-69

Configuration and motion
Displacement
Velocity and acceleration
Material and spatial derivatives

Tue 04/14 **Kinematics II - Deformation gradient**
Chapter 2.4,2.6, pages 70-75, 85-94

Stretch
Deformation gradient
Rotation and stretch tensors
Right and left Cauchy-Green tensors

Thu 04/16 **Kinematics III - Strain**
Chapter 2.5,2.7,2.8, pages 76-84, 95-108

Strain tensors
Normal and shear strain
Maximum principal strain
Lie derivative

Tue 04/21 **Concept of stress**
Chapter 3.1-3.4, pages 109-130

Traction vector and stress tensor
Stress tensors
Normal and shear stress
Maximum principal stress

Thu 04/23 **Balance principles I - Mass and momentum**
Chapter 4.1-4.3, pages 131-151

Balance of mass
Reynolds' transport theorem
Balance of linear and angular momentum
Cauchy's first equation of motion

Tue 04/28 **Balance principles II – Energy and entropy**
Chapter 4.4-4.7, pages 152-178

Kinetic and internal energy
Balance of energy
Entropy inequality
Master balance principle

Thu 04/30 **Aspects of objectivity**
Chapter 5.1-5.4, pages 179-205

Change of observer and objectivity
Superimposed rigid body motion
Objective rates
Invariance

Tue 05/05 **Hyperelasticity I - General remarks**
Chapter 6.1, 6.6, pages 205-211, 252-264

General remarks
Strain energy function
Second law of thermodynamics
Stress and elasticity tensors

Thu 05/07 **Hyperelasticity II - Isotropy**
Chapter 6.2, pages 212-221

Invariant-based formulation
Tensorial formulation
Stretch-based formulation
Examples

Tue 05/12 **Hyperelasticity III - Incompressibility and compressibility**
Chapter 6.3-6.4, pages 222-234

Incompressiblity
Incompressible isotropic hyperelasticity
Compressibiliy
Compressible isotropic hyperelasticity

Thu 05/14 **Hyperelasticity IV - Strain energy functions**
Chapter 6.5, pages 235-251

Ogden model
Mooney Rivlin model
Neo Hooke model
Varga model

Tue 05/19 **Hyperelasticity V - Transverse isotropy**
Chapter 6.7, pages 265-277

Fibers and stretch
Pseudo-invariants
Incompressible transversely isotropic hyperelasticity
Multiple fiber families

Thu 05/21 **Inelasticity**
Chapter 6.9,6.11, pages 278-281, 295-304

Concept of internal variables
Hyperelasticity with Damage
Strain energy function
Stress and moduli

Tue 05/26 **Prep final**
Chapter 1-6, pages 1-304

Vectors and tensors
Kinematics
Balance principles
Constitutive equations

Thu 05/28 **Final**

Tue 06/02 **Selected topics**

Thu 06/04 **Selected topics**

Fri 06/05 **Final projects due**