BIOMEDE/ME 456: TISSUE MECHANICS
FALL 2018
Class Schedule: MW 8:30 AM - 10:00 AM, 1121 LBME

The course is divided into 2 parts:

Part I: Introduction to Continuum Mechanics relevant to Biological Tissues

Covers the fundamentals of continuum mechanics and constitutive modeling relevant for biological materials. Constitutive models covered include:

1. Linear Elasticity
2. Nonlinear Elasticity
3. Viscoelasticity
4. Optimization methods to fit mathematical models to collected mechanical testing data in MATLAB

Part II: Finite element modeling of tissue behavior using MIMICS/3-matics, HyperMesh, and COMSOL

Instructor:
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Office Hours in LBME 2185:
Mondays: 10-11:30am
Wednesdays: 10-11:30am
or send email to set up an appointment

Grader: Nicole Chen (nicchen@umich.edu)

GSI: Tiana Wong (tjwong@umich.edu)
Office Hours in LBME 2189:
Tuesdays and Thursdays: 1-3 pm.

Texts
Available online through the library:
Modelling Organs, Tissues, Cells and Devices Using MATLAB and COMSOL Multiphysics / — Socrates Dokos.
Cardiovascular Solid Mechanics Cells, Tissues, and Organs /—Humphrey, Jay D., author.
Continuum mechanics for engineers — George Mase
A Concise Introduction to Linear Algebra — Géza Schay
Tensor Algebra and Tensor Analysis for Engineers With Applications to Continuum Mechanics — Itskov, Mikhail
Math refresher for scientists and engineers — John R. Fanchi

Recommended study guides:
Schaum's Outline of Linear Algebra

Schaum's Outline of Continuum Mechanics

Grading Criteria:

25% Homework (includes writing, MATLAB, and FEM assignments)
45% Biomechanics Project (written and oral components):
30% Midterm

General Course Policies:

Attendance at the lectures is not mandatory **unless there is a guest speaker**. Exams will include questions from the guest speaker and the absent student is expected make arrangements with another student to obtain notes. Attendance and participation will be considered in assigning letter grades in borderline cases.

Students who must reschedule exams and or assignments due to religious observances or other personal matters should notify the instructors in advance. Students with disabilities who require special accommodations during classes or examinations should contact the Office of Services to Students with Disabilities to ensure that appropriate arrangements are made. The student is responsible for reminding the instructor of conflicts due to team activities and requirements for special accommodations as the need arises.

Assignments and examinations will be graded and returned to students as soon as possible after being handed in. Students should check the grading carefully. Any grade appeals must be submitted in writing within one week of the return of the assignment or exam.

Emails will be answered within 48hrs of receiving them. Proper email etiquette is expected for any communications with the instructor or GSI. **Please include [BME456 or ME456] in the subject line of all emails.**

All students in this class are bound by the College of Engineering Honor Code. You may not seek to gain an unfair advantage over your fellow students; you may not consult, look at, or possess the unpublished work of another without their permission; and you must appropriately acknowledge your use of another's work. Any violation of the honor policies appropriate to each piece of course work will be reported to the Honor Council, and if guilt is established penalties may be imposed by the Honor Council and Faculty Committee on Discipline. Such penalties can include, but are not limited to, letter grade deductions or expulsion from the University. Collaboration policies on individual assignments will be described in the assignment handout. If you have any questions about the policies in this course, please consult the course instructor.

Topics to be covered (subject to change): Note that HW due dates may be adjusted based on the speed through the syllabus.

Lect.	Date	Assignments	Lecture Topic	Chs.
1	9/5		Class Overview/History of Continuum Mechanics Class Motivation	0/1
2	9/10	**Top 3 tissue choices due**	Mathematical Foundations/Indicial Notation	2
3	9/12		Indicial Notation/Deformation and Strain 1) Define the assumptions made while we are deriving the linear elastic equations (recall that these model idealized materials) 2) Mapping between the undeformed deformed coordinate systems using the deformation tensor: F_{ij}	2/3

			3) Derive the infinitesimal and finite strain tensors: ε_{ij}, E_{ij} 4) Left and right Cauchy strain tensors: B_{ij}, C_{ij}	
4	9/17	***HW#1 due***	Stress for LE materials and NLE materials 1) Cauchy (true) stress: σ_{ij} 2) Equations of motion: $\partial \sigma_{ij} / \partial x = 0$ 3) Calculating surface stresses: $t_i = \sigma_{ij} n_j$	4
5	9/19	**Draft of mechanical testing protocol due**	Stress for LE and NLE materials Strain Energy Density (W) and energetic equality: $\sigma_{ij} = \partial W(\varepsilon_{ij}) / \partial \varepsilon_{ij} = \partial W(B_{ij}) / \partial B_{ij}$ $T_{ij} = \partial W(F_{ij}) / \partial F_{ij}$ $S_{ij} = \partial W(E_{ij}) / \partial E_{ij} = 2\left[\partial W(C_{ij}) / \partial C_{ij}\right]$ LE constitutive model/Mechanical Isotropy Cauchy stress: $\sigma_{ij} = P/A = C_{ijkl} \varepsilon_{kl}$ 1) 1st PK: $T_{ij} = P/A' = J \sigma_{ik} F_{jk}^{-1}$ 2) 2nd PK: $S_{ij} = P'/A' = J F_{ik}^{-1} \sigma_{kr} F_{jr}^{-1}$	4
6	9/24		NLE constitutive model/Assumptions of Incompressibility 1) SED as a function of invariants 2) Specific tissue models: Ogden, Mooney-Rivlin, Neo-Hookean	5
7	9/26	***HW#2 due***	NLE constitutive model/Viscoelasticity	6
8	10/1		Viscoelasticity	6
9	10/3	**Final mechanical testing protocol due**	Fitting Non-Linear Elasticity Models in MATLAB	7
10	10/8		Fitting Non-Linear Elasticity Models in MATLAB	7
	10/10	***HW#3 due***	Midterm Review	
	10/15		Fall Break	
	10/17		**MIDTERM**	
12	10/22		Overview of Finite Element Theory/Numerical methods to solve PDEs and ODEs	8
13	10/24		Overview of Finite Element Theory/ Numerical methods to solve PDEs and ODEs	8
14	10/29		Introduction to COMSOL: LE cube	9
15	10/31		Introduction to COMSOL: Cartilage defect model	9
16	11/5	***HW#4 due***	Creating Simple LE and NLE Finite Element Models from STL using HyperMesh and COMSOL (CAEN lab)	10
17	11/7	**Mechanical testing FINAL report due**	Optimization/ data fitting in COMSOL	10
18	11/12		Input of Time-dependent functions in COMSOL	12
19	11/14		Modeling contact in COMSOL (roller)	Tut.
20	11/19		Introduction to Mimics I: Basic Segmentation (CAEN lab)	13
	11/21		**No class**	
21	11/26		Introduction to Mimics II: Advanced Segmentation (CAEN Lab)	14
22	11/28		Introduction to Mimics III: FE meshing in 3matic (CAEN lab)	
23	12/3	***HW#5 due***	Advanced Modeling in COMSOL: (Balloon inflation-VE tube)	Tut.
	12/5		Advanced Modeling in COMSOL: Viscoelastic tissue Modeling of the aorta (CAEN lab)	16
	12/10		Work on projects	
	12/20	8am-10am	**Biomechanics Project Presentations**	