BIOMEDE 332: INTRODUCTION TO BIOMECHANICS
WINTER 2018
Class Schedule: TR 10:30 AM - 12:30 PM, 1121 LBME

Overall course objective: Student will learn to convert conceptual ideals into mathematical relationships that allow us to calculate stress given deformation by integrating basic mechanics (balance of forces, moments, and energy) with mathematical principles (Vector Calculus and Linear Algebra)

This course 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

Structure-function relationships which link tissue morphology and physiology to tissue constitutive models will be covered for skeletal, cardiovascular, pulmonary, abdominal, skin, eye, and nervous tissues.

The course is divided into 2 parts:

1. Introduction to Continuum Mechanics relevant to Biological Tissues
2. Application of Continuum Mechanics concepts to study Tissue Mechanics

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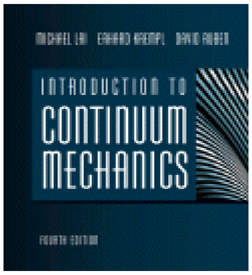
Instructor:
Rhima Coleman (rhimacol@umich.edu)
Assistant Professor
Department of Biomedical Engineering
Office: 2170 LBME

Office Hours in LBME 2189:
Tuesdays and Thursdays: 12:30 PM - 1:30 PM
or send email to set up an appointment

GSIs:
Tiana Wong (tjwong@umich.edu)
Office Hours in LBME TBD or by appointment
Grader: Camila Luciano (cluciano@umich.edu)

Texts:
Available online through the library



Introduction to Continuum Mechanics, (Fourth Edition) - W. Michael Lai, David Rubin and Erhard Krempl

ISBN: 978-0-7506-8560-3

Texts

Available online through the library:

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

On reserve at the library

Nonlinear solid mechanics – Holzapfel (QA808.2 .H655 2000)

Recommended texts:

Schaum's Outline of Linear Algebra
Schaum's Outline of Continuum Mechanics

Grading Criteria:

- 15% Homework
- 10% Oral presentation of a Biomechanics Paper
- 15% Quizzes (4 in-class; 3 online)
- 30% Midterm
- 30% Final Exam

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. I**nclude [BME332] in the subject line of all emails or it will get lost.**

Honor Code:

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 quiz and HW due dates will be adjusted based on the speed through the syllabus.

Learning objectives:
Will be abbreviated LOs in the schedule

Lect#	Date	Assignments/ Quizzes	Lecture Topic	Reading
1	1/4		Class Overview Class Motivation	Coleman-Chapter 1
2	1/9		**Mathematical Foundations** Brief History of continuum mechanics Matrix manipulations (Linear Algebra)	Coleman-Chapter 2
3	1/11		**Mathematical Foundations** Indicial Notation	Lai – CH 2 Coleman-Chapter 2
4	1/16		**Mathematical Foundations** Vector Calculus	Lai – CH 2 Coleman-Chapter 2
5	1/18	***HW#1 due*** **Quiz#1**	**Linear Elasticity:** Assumptions/Deformation and Strain *LOs:* 1) Define the assumptions made while we are deriving the linear elastic equations (recall that these model idealized materials) 2) Derive an equation for deformation as a function of measurable quantities (x_i' and x_i) using vector addition	Lai – CH 3.5, 3.18-25 Coleman-Chapter 3
6	1/23		**Linear Elasticity:** Deformation and Strain *LOs: Derive equations:* 1) Derive deformation tensor F_{ij} : maps the undeformed coordinates of a vector in space to the deformed coordinates using the chain rule 2) Derive the infinitesimal strain tensor ε_{ij} using geometry and small strain assumptions	Lai – CH 3.5, 3.18-25 Coleman-Chapter 3
7	1/25	***HW#2 due***	**Linear Elasticity:** Stress *LOs: Understanding the concepts of the stress tensor and stress vector* Derivation of the Cauchy stress tensor σ_{ij} : maps the normal vector (n_j) to the stress vector (t_i) using balance of forces (Newton's 2nd Law)	Lai – CH 4.1- 4.3 Coleman-Chapter 4
8	1/30		**Linear Elasticity:** Stress *LOs: Understanding the concepts of the stress tensor and stress vector* 1) Demonstrate stress symmetry using the balance of moments (Newton's 3rd Law) 2) Calculating stress on a plane 3) Derivation of the equations of motion	Lai – CH 4.4- 4.7 (4:18 demonstrates derivation from integral forms) Coleman-Chapter 4
9	2/1		**Linear Elasticity:** Constitutive Equations *LOs:* Understanding strain energy density 1) Derive Hooke's Law from a strain energy function ("As the extension, so the force."- Hooke 1660)	Lai – CH 5.1-5.5; 5.13-5.14, Coleman-Chapter 5

10	2/6	**Quiz#2** ***HW#3 due***	**Linear Elasticity:** Constitutive Equations 2) Application of Hooke's Law 3) Simplifications of Hooke's Law due to symmetry	Lai – CH 5.18-5.19; 5.46-5.54 Coleman-Chapter 5
11	2/8	***HW#4 due***	**Cortical Bone:** length scales of bone mechanics	Coleman-Chapter 6
12	2/13		Principles of Bone Biomechanics to Understand Bone Function and Adaptation - David Kohn, PhD	Coleman-Chapter 6
13	2/15	***HW#5 due***	**Trabecular Bone:** Length scales of bone mechanics Stereology and the fabric tensor	Lecture slides
	2/20		Review	
	2/22		**EXAM #1**	
2/23-3/4 Spring Break				
14	3/6		Large deformations: Alternate def. of strain and stress Derive nonlinear strain equation Define stress for nonlinear conditions in the undeformed and reference states	Lai – CH 4.1-4.5, 4.7 Lai – CH 4.10-4.11 Coleman-Chapter 7
15	3/8		Large deformations: Alternate def. of strain and stress Define stress for nonlinear conditions in the undeformed and reference states Nansons' equation required to map area	
16	3/13	**Quiz#3** ***HW#6 due***	Non-linear Elasticity Strain energy forms for specific types of materials: Isotropic, Incompressible, Transversely isotropic	
17	3/15		Non-linear Elasticity Specific models: Ogden, Mooney-Rivlin, Neo-Hookean	Holzapfel 5.6-6.6 ; 6.7-6.8 Coleman-Chapter 8
18	3/20		**Guest Lecturer: TBD**	Lecture slides
19	3/22		Guest Lecturer: Fitting material models to experimental data for the anterior cruciate ligament	
20	3/27	**Quiz#4** ***HW#7 due***	Viscoelasticity	Coleman-Chapter 11
21	3/29		Viscoelasticity	Coleman-Chapter 11
22	4/3		Viscoelasticity	Coleman-Chapter 11
23	4/5	***HW#8 due***	**Literature Discussion:** At least three invariants are necessary to model the mechanical response of incompressible, transversely isotropic materials. Comput Mech (2013) 52:959	
	4/10		**Biomechanics Paper Presentations**	
	4/12		**Biomechanics Paper Presentations**	
	4/17		Finals Review	
	4/23		Final 4:00-6:00pm	